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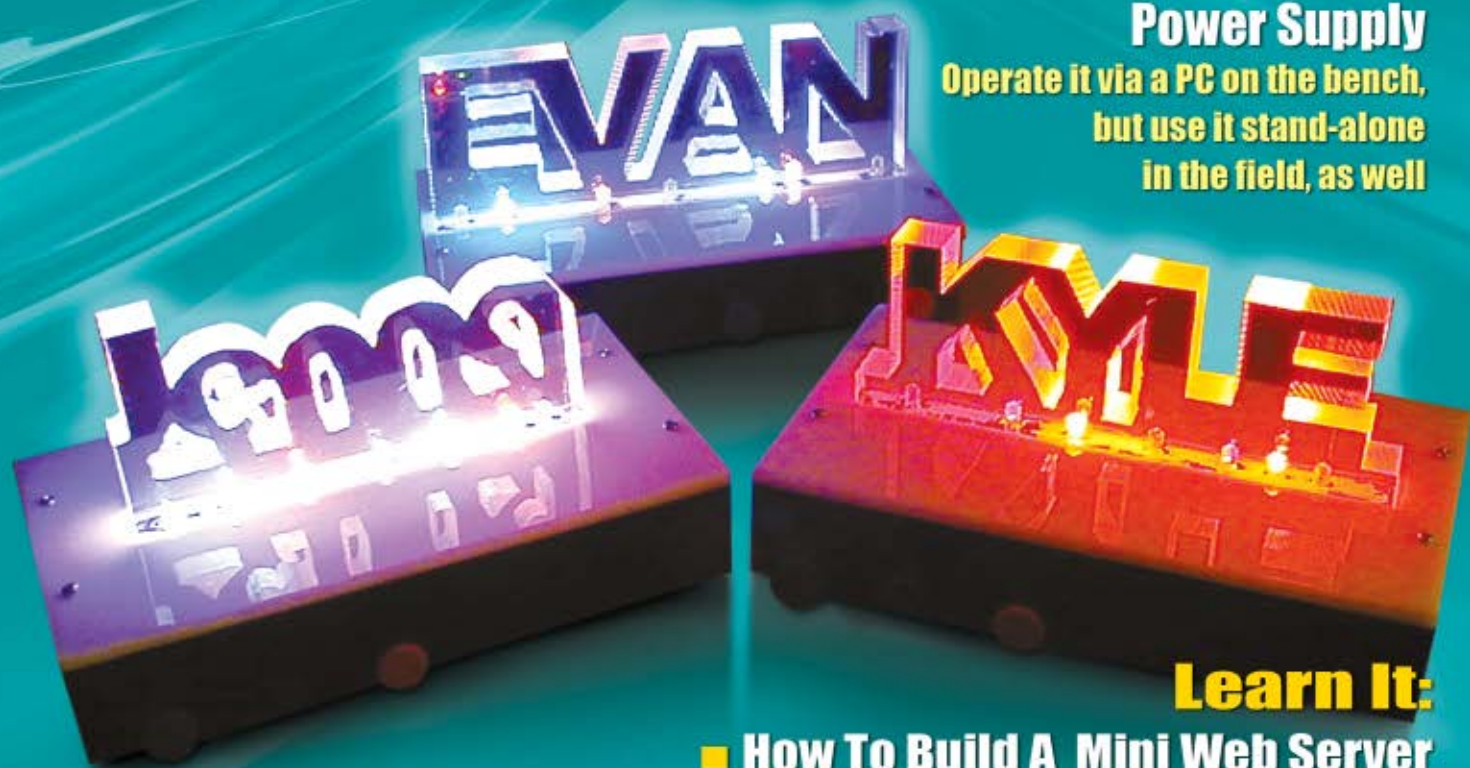
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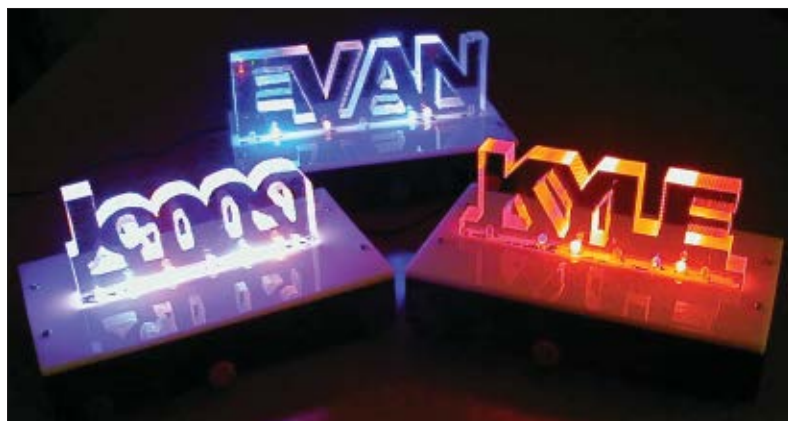
Projects

34 BUILD THE ILLUMINAME

Put your name in lights with LEDs.

■ By Jules Ryckebusch

●●●● Advanced Level



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39 REMOTELY PROGRAMMABLE POWER

This device works with older hardware and software, plus can operate stand-alone so it's perfect for applications out in the field.

■ By Paul Lapsansky

●●●● Advanced Level

Be sure to check the Nuts & Volts website for downloads that go along with these projects.



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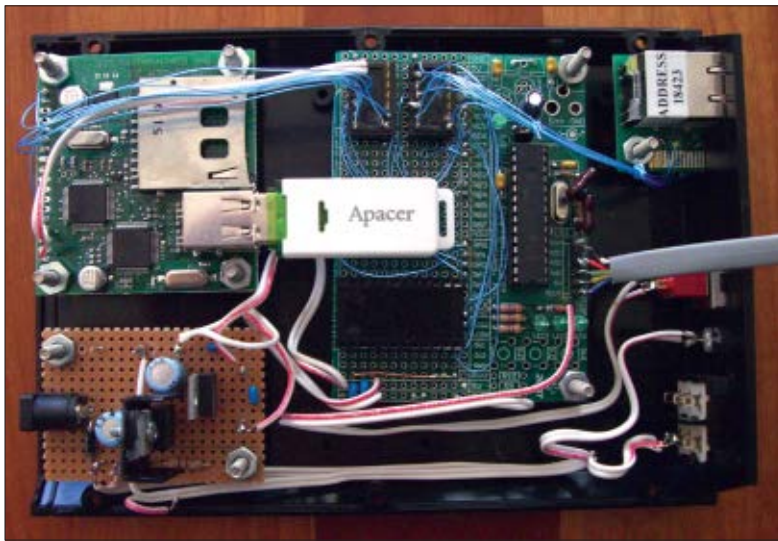
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Nuts & Volts (ISSN 1528-9885/CDN Pub Agree #40702530) is published monthly for \$24.95 per year by T & L Publications, Inc., 430 Princland Court, Corona, CA 92879. PERIODICALS POSTAGE PAID AT CORONA, CA AND AT ADDITIONAL MAILING OFFICES. POSTMASTER: Send address changes to **Nuts & Volts, P.O. Box 15277, North Hollywood, CA 91615** or Station A, P.O. Box 54, Windsor ON N9A 6J5; cpcreturns@nutsvolts.com.



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Use this low power alternative to run your personal website.

■ By Craig Lindley

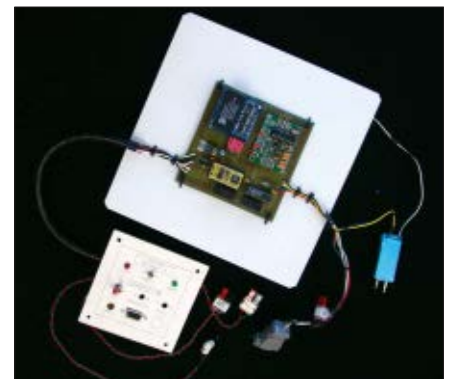
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Joe takes us on his journey of making the coolest attendee badge ever.

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Power Flowers.



by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

GPS Tracking

One of my first jobs in electronics was helping a security specialist clear safe houses of bugs and phone taps. Paradoxically, the specialist also made a good living planting bugs, tapping phones, and recording the movement of people, vehicles, and other assets. Back then, in the pre-LoJack era, the primary means of tracking included film-based photography, manual odometer readings, and RF triangulation of short-lived, low-power RF transmitters planted on vehicles.

Today, electronics continue to play a central role in maintaining the security of government and business offices, and tracking the movement of persons of interest. While miniature cameras have many uses in electronic surveillance, tracking is increasingly reliant on low-cost GPS receivers. You've probably seen or read about the GPS-based ankle bracelets for prisoners on house arrest, collars for dogs, and watches for children and the elderly that enable a guardian to monitor the wearer's whereabouts. However, these systems are generally closed and require a subscription service to enable the reporting features. Fortunately for the experimenter, the same technology used in these GPS-based tracking services is available in accessible, affordable packages. Microprocessor-friendly GPS modules are available from Parallax (www.parallax.com) and SparkFun Electronics (www.sparkfun.com), among others.

The Parallax GPS Receiver Module, shown in Figure 1, is an affordable (\$90) way to get your feet wet in GPS tracking, whether for a tracking system, robot navigation, or

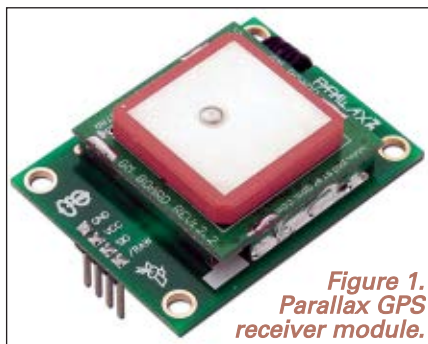


Figure 1.
Parallax GPS receiver module.



Figure 2. Micro-miniature GPS receiver from SparkFun Electronics.

mapping. If, like me, you're a Stamp fan, then the module is hard to beat, given its Stamp-ready hardware interface. My main reservation with the Parallax offering is that the source code for the programmable Parallax SX microprocessor associated with the module isn't supported by Parallax.

SparkFun Electronics is my favorite source for hard-to-find and one-of-a-kind miniature components and assemblies. They offer a dozen different GPS modules in the \$55-\$75 range, including the micro-miniature GPS receiver shown in Figure 2. However, unless you're really good with a hot air pencil, you're probably better off with one of their slightly larger modules with built-in antenna and connectors, a complete GPS logger kit, or a finished (but accessible) GPS logger. The SparkFun GeoChron GPS Logger, shown in Figures 3 and 4, is a ruggedized assembly of their EM408 GPS receiver and antenna (\$65), 1 Ah lithium polymer battery, built-in charger circuit, and SD card reader/writer. The GeoChron seems designed to be modified, given the ease with which the unit can be disassembled. It sells for

\$150, without SD card or DC charger. Although sturdy, the GeoChron isn't something you can slip unnoticed into a pocket. It measures 4-1/8 x 2-3/4 x 1 1/8" and weighs just over 5 oz. It is easy to set up and use. Simply insert a blank SD card in the slot at one end of the unit and turn on the power. The unit writes a setup file to the card which you can modify with a text editor to specify what data to record and the update frequency. The interface is easy to learn and consists of a status LED and two rocker switches. I'd prefer recessed switches to prevent accidentally powering down the unit, but the switches do require a fair amount of force to operate. The logger runs for a little over seven hours if you opt for continuous tracking — and up to several days if you configure the unit to write to the SD card less frequently. The GeoChron can sleep for 500 hours. I like the SD card feature because it's a simple matter to eject the card from

Figure 3. GeoChron GPS logger.



Figure 4. GeoChron revealed.



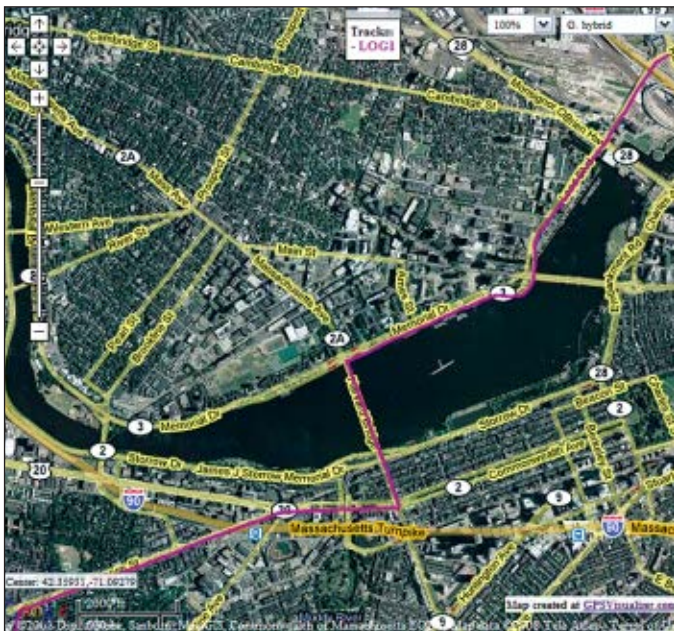


Figure 5. GPS Visualizer output. Tracking path shown in purple.

the unit, pop it into an SD reader, and upload the tracking file to one of several free GPS mapping sites, such as GPS Visualizer (www.gpsvisualizer.com). GPS Visualizer converts the tracking data to a path displayed on a Google Earth map (www.earth.google.com).

To test the GeoChron, I tossed the unit into my bike panniers to track my daily commute. When I arrived at work, I uploaded the tracking file to GPS Visualizer. The output, shown in Figure 5, consists of the purple line tracing my trek from Brookline to Cambridge, MA. Applications range from route analysis to determine if a commercial driver took the shortest routes, to monitoring use of the family car. There are other affordable GPS-based tracking options, including the SPOT Satellite Personal Tracker (www.spotgpspersonaltracker.com), available from REI (www.rei.com) and other recreation retail outlets. With the \$150 unit designed for use in remote areas without cell phone coverage, you can pinpoint your location to friends or alert a 911 dispatcher to send in the rescue helicopters. There is a modest annual service fee for the satellite service subscription. SPOT, GPS-enabled sports watches, and other personal trackers are excellent uses of GPS technology. However, unlike the GeoChron or Parallax GPS module, they're closed systems that don't lend themselves to experimentation — and that's what we're all about. **NV**

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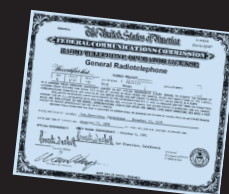
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WHAT'S IN A MICROCONTROLLER

Regarding the Pop Quiz (Schematic Fanatic, *Nuts & Volts*, May '08, page 63) ... the use of the term "microcontroller" is very misleading. Both the generic 74LS373 and the generic 4028 devices are, in fact, sequential logic, and have nothing to do with a microcontroller function as defined by Wikipedia (<http://en.wikipedia.org/wiki/Microcontroller>).

While it is not necessary to understand these devices in detail to follow the article, it would be helpful to the reader to have the right context. Sequential logic has memory, combinational logic does not and follows the rules of Boolean algebra. Microcontrollers have a much greater level of complexity allowing the programming and execution of firmware instructions. I think it's important to get the theory and industry accepted terminology correct, more so in a tutorial article or quiz.

Peter J. Stonard
Campbell, CA

Response: Peter, you are absolutely right. A typical microcontroller is comprised of an internal processing engine, supporting program and data memory, and an I/O subsystem. Today's microcontrollers are self-contained, externally-programmable

units that typically use non-volatile Flash memory technology for program memory and volatile SRAM (Static Random Access Memory) for data memory and working register storage.

In contrast, the 74LS373 and CD4028 devices are not user programmable and do not contain program Flash or SRAM data memory elements. The 74LS373 and CD4028 are actually special-purpose integrated circuits. Another good description for the 74LS373 and CD4028 would be complex integrated circuits.

The 74LS373 was designed to interface external memory and I/O devices to address and data busses of microcontrollers and microprocessors. A 74LS373 IC is actually a collection of eight independent D latches. In the case of the 74LS373, each D latch can act as a one-bit latch-based memory element or simply pass (buffer) the logic level on an input pin to the associated output pin. The outputs of the D latches within the 74LS373 have the ability to isolate themselves from the microcontroller or microprocessor bus to which they are attached. This ability to logically detach from the bus is described as 3-STATE or TRI-STATE operation.

The CD4028 is a bit more internally complex than the 74LS373 in that the CD4028 was designed as a BCD-to-decimal or binary-to-octal decoder.

continued on page 60

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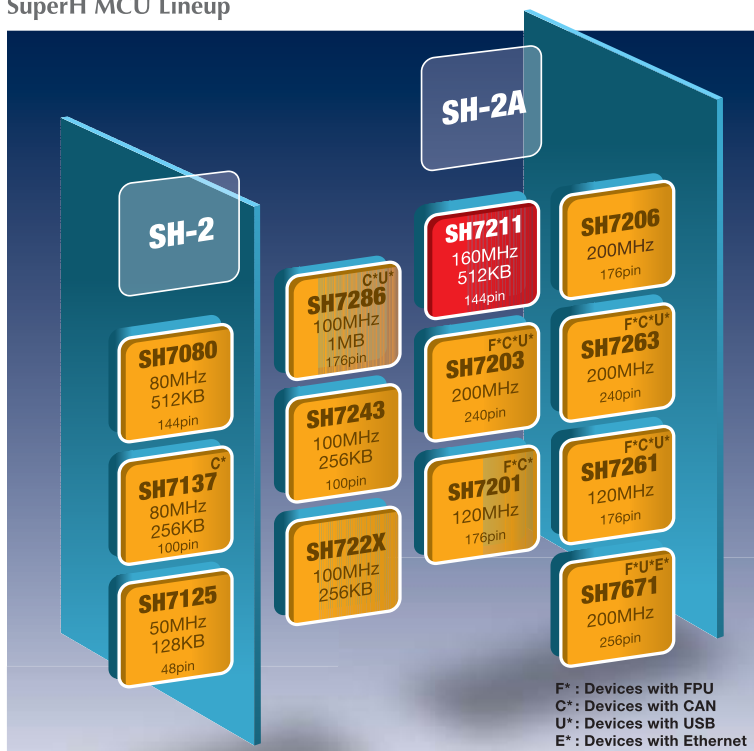
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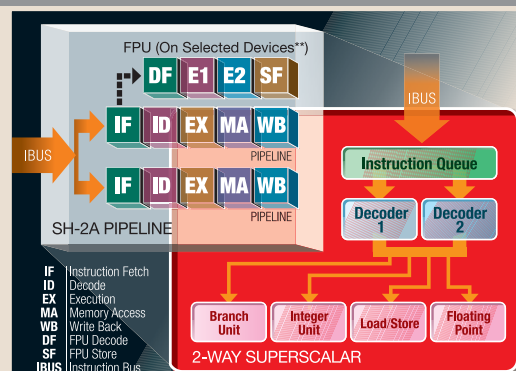
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*Source: Gartner (March 2007) "2006 Worldwide Microcontroller Vendor Revenue" GJ07168



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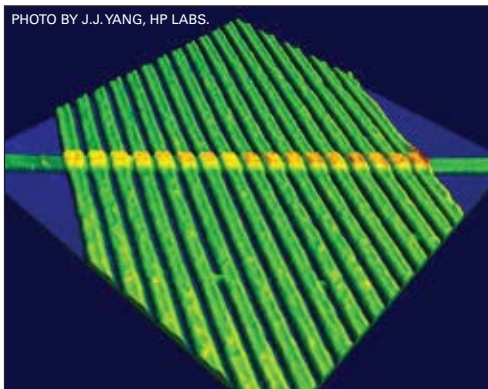
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■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

37-YEAR-OLD MYSTERY SOLVED

PHOTO BY J.J. YANG, HP LABS.



■ An atomic force microscope reveals 17 memristors in a row. The wires are 50 nm (about 150 atoms) wide.

At the rudimentary level, when you're building an electrical circuit, you have only three basic elements to work with: resistors, capacitors, and inductors. But back in 1971, electrical engineer Leon Chua published a paper theorizing that there must be a fourth one, with properties that cannot be duplicated by any combination of the others. He dubbed this mysterious component the "memristor" (for "memory resistor"). The problem was that he couldn't find anything that displayed memristance. Flash forward to the 1990s, when some researchers at Hewlett Packard Labs (www.hpl.hp.com) were exploring the electrical properties of some nanotech materials. Noticing that a few of them looked a lot like what Chua described, they decided to try to invent one. It now appears that they succeeded.

To achieve memristance, you need to cause atoms to change location by applying a voltage, which doesn't happen easily outside the nanoscale realm. But 37 years after Chua's paper, it proved to be relatively simple: The HP engineers just put

together two layers of titanium dioxide semiconductor sandwiched between electrodes. The bottom layer is a nonconductor, and the top is short a few oxygen atoms, which creates positively charged "bubbles" that make it a conductor. Hitting the top electrode with a positive charge pushes some of the bubbles into the lower layer, where they remain until another charge is applied. A computer can read the data contained in the memristor cell by measuring its resistance. The intriguing thing is that relatively high voltages can produce the usual one/zero digital values, but lower voltages can produce intermediate values, so it has profound implications in the analog world, as well. And the values are cumulative with successive voltage zaps, so the device can "learn" over time, sort of like the human brain. At present, the devices measure about 15 nm across and store about 100 Gb/cm². But HP thinks they can be shrunk to 4 nm or less, at which point you could store 1 Tb in one.

The most obvious application of the concept is to replace today's DRAM devices with an IC that will retain data without continuous power, which would lower power consumption and eliminate the lengthy boot-up process in a range of digital devices. But team leader Stan Williams even speculated about an analog computer that thinks the way we do. "This opens up a whole new door in thinking about how chips could be designed and operated," he observed.

Prof. Chua, by the way, is alive and well in the Electrical Engineering and Computer Sciences Department of the University of California Berkeley, so somebody please send him some money. He's waited a long time.

DEVICE TO HARNESS TERAHERTZ RADIATION

University of Utah (www.utah.edu) engineers are taking a different track toward the future of computing, taking aim at circuits that run on far-infrared light (a.k.a., terahertz radiation or T-rays) instead of electrons. It's not so difficult to move T-rays from one point to another through a waveguide, but for computing purposes you also have to process the signal. The first step seems to have been taken by Prof. Ajay Nahata and colleagues, who recently demonstrated a waveguide device that makes it possible to transmit, bend, split, or combine terahertz radiation.

To accomplish the feat, they started with a 4 x 1 in (100 x 25 mm) piece of stainless steel, 625 μ m thick. Then they perforated the metal with a pattern of rectangular holes, each measuring 50 x 500 μ m, thus forming the equivalent of wires. By using a line that splits into two "Y" patterns, they managed to split the light the way you might use an electrical splitter to steal your next door neighbor's TV cable signal. And by arranging two lines that nearly converge in the middle (see photo), they "coupled" it from one wire to the other.

Tests verified that the radiation — in the form of surface plasma waves or "plasmons" — was confined vertically to within 1.69 mm of the foil's surface and within 2 mm of the perforation

■ Close-up of a terahertz waveguide device.



PHOTO BY WENQI ZHU.

patterns horizontally. This is indeed just the first step, though. As Nahata acknowledged, "Now the issue is, how do we make devices (such as switches, transistors, and modulators) at terahertz frequencies?"

COMPUTERS AND NETWORKING

LOTS OF FLOPS

As of the last assessment by **TOP500.org** (last November), the fastest computer in the world was still IBM's BlueGene/L system, which resides at Lawrence Livermore National Laboratory and achieves a Linpack benchmark performance of 478.2 TFLOPS. But NASA (www.nasa.gov) has ordered a new Altix® ICE machine that, although warming up at a paltry 245 TFLOPS this summer, should pass the PFLOP level next year and be steaming along at 10 PFLOPS by 2012. (Compare this to the human brain's pathetic 100

TFLOPS, which ebbs with normal wear and tear.) Yes, that's 10 quadrillion floating point operations per second. One billion million. If you had a grain of salt for each FLOP, the pile would take up more than 35 million cubic feet. That's more than Long John Silver's uses in an entire fish 'n chips platter.

Anyway, built by SGI (www.sgi.com), the new monster will sport 20,480 Intel Xeon processor cores, more than 20,800 GB of main memory, and 450 TB of data storage. Among its primary tasks is to support NASA's aeronautics, science, and space operations, including scheduled manned missions to the Moon and Mars. It will be housed in the agency's Advanced Supercomputing facility, Ames Research Center, in Mountain View, CA.

CHEAP PC RUNS OS X

At the lower end of the scale is the new Open Computer PC from Miami-based Psystar Corp. (www.psystar.com). Not only will the \$399 machine run Ubuntu Linux 8.04 and Windows XP or Vista, it can also run the Mac OS X Leopard right out of the box (preloaded for an extra \$155), thus explaining its nickname, the "Hackintosh." Given that Apple's license agreement forbids running OS X on anything that doesn't have an Apple brand on it, there is some question about the legality of the arrangement. But demand has been so strong that Psystar's online store initially collapsed under the weight of the traffic.

The base configuration includes Linux, a 2.2 GHz Intel Core 2 Duo E4500 processor, 2 GB of DDR2 memory, integrated Intel GMA 950 graphics, a 20x DVD drive, gigabit Ethernet, and four USB ports. According to tests conducted by the folks at Computerworld, it runs about 28 percent faster than a \$799 Mac mini and only eight percent

slower than an \$1,199 iMac.

FREE VIDEO SITE OPEN

If you've been waiting for a good source of free TV shows, movies, and clips from major studios, well, you're getting closer. In March, Hulu (www.hulu.com) went online with licensing deals from Warner Bros., Lionsgate, the NBA, the NHL, and 20 other content providers. According to CEO Jason Kilar, "Hulu is crossing a milestone in its mission to help people find and enjoy the world's premium content, when, where, and how they want it. With full-length episodes of current and archived television shows, feature films, sports, and news, we believe the Hulu service is a step forward in giving consumers entertainment on their terms."

The drawbacks are that, as of this writing, the programming selection is highly limited and, of course, you don't exactly get HDTV. And just like on your cable channel, you can expect commercials before and during the clips. But at least it's free.

WEIRDEST WEBSITE?

This month's nominee for the strangest website goes to **urinal.net**, billed as "the best place to p*ss away your time on the Internet?." A good starting point is the Top 10 Urinals link, where you can view the facilities at such diverse places as the Taj Mahal, the International Space Station, and a Dairy Queen in Port Charlotte, FL. My personal favorite is the Felix bar and restaurant, atop Hong Kong's Peninsula Hotel. But that one is not for the acrophobic, as you drain yourself into a granite fixture while gazing at the Kowloon skyline from the 28th floor. And it's not for the tight fisted, either; rooms start at \$513 and ratchet up to \$8,700 per day for the Peninsula Suite. **Urinal.net** even offers an interactive map of 741 noteworthy relief locations to help you plan your next vacation. No doubt about it, the Internet really does have something for everyone, no matter how deranged.



PHOTO COURTESY OF SGI.

■ This Altix ICE supercomputer may (coincidentally?) look like a circuit breaker box full of ice cube trays, but its descendent will eventually turn 10 PFLOPS.

INDUSTRY AND THE PROFESSION

DOE REPORT ANALYZES US WIND RESOURCES

The US Department of Energy (DOE) recently released a new report that examines the technical feasibility of using wind power to generate up to 20 percent of our energy needs. Entitled "20 Percent Wind Energy by 2030," the report identifies the hurdles, including reducing the cost of associated technologies, creating a new transmission infrastructure, and enhancing domestic manufacturing capability. The report also identifies opportunities for avoiding 7.6 cumulative gigatons of CO2 emissions by 2030, saving 825 million metric tons in 2030 and every year thereafter. According to a DOE representative,

"DOE's wind report is a thorough look at America's wind resource, its industrial capabilities, and future energy prices, and confirms the viability and commercial maturity of wind as a major contributor to America's energy needs, now and in the future." To download your own copy of the 248-page document, just go to www.jkeckert.com/downloads.html.

BETA TESTERS NEEDED

At least as of this writing, SchmartBoard, Inc., is looking for people to beta test a new website called Solder By Numbers™. Scheduled to launch in late summer, it is billed as a "social network for electronics enthusiasts." Details have not been revealed, but it is essentially web 2.0 and a place to "design and build your electronic circuits while you create a worldwide network of peers ... It will be a place to collaborate, create, communicate, and learn." To sign up, visit www.solderbynumbers.com.

CIRCUITS AND DEVICES

WORLD'S SMALLEST SAR

It's not something that will be on the average N&V reader's shopping list, but it's intriguing nonetheless. Whereas most synthetic aperture radars (SARs) weigh somewhere between 50 and 200 lbs (23 to 91 kg), Boeing (www.boeing.com), in partnership with ImSAR and Insitu, Inc., has successfully tested NanoSAR, billed as the world's smallest unit. The 2 lb (0.9 kg) device proved itself during a 1.5 hr test flight aboard a ScanEagle unmanned aircraft. It completed several passes at various altitudes and ranges over a test area, detecting vehicles, structures, and corner reflectors.

This incarnation of the SAR collects data that is later used to create imagery, but future versions will be able to do that in real time. According to Chief Engineer Carol Wilke, "The NanoSAR technology's ability to see in hazy, cloudy, rainy, or foggy conditions is ideally suited for the maritime environment." A prime

mission will be to locate small vessels on the ocean from aboard the ScanEagle, which can operate autonomously at altitudes of 16,000+ ft.

RF FILTERS INTRODUCED

If you need a small, wide frequency range RF filter, either standard or custom, the μ FILTER™ from NuWAVES (www.nuwaves-ltd.com) may be of interest. The custom frequency (CF) modules offer multiple pole configurations in the four usual types: band pass, low pass, high pass, and band reject; designed for a typical 20 percent or greater bandwidth. Typical frequency ranges are 70 MHz to 1 GHz.

The standard frequency (SF) modules come in a frequency range up to 2.4 GHz. All are packaged in a 1.0 x 0.75 x 0.5 in (25.4 x 19 x 12.7 mm) ruggedized aluminum housing and feature SMA connectors. These aren't your standard RadioShack components, though. In small quantities, they will run you at least \$250.

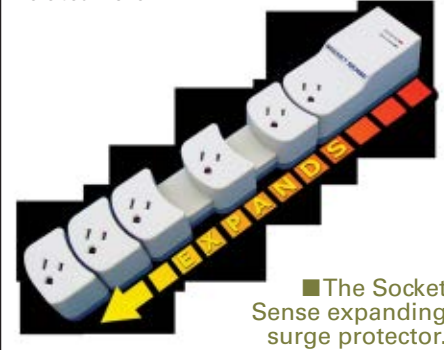
PHOTO COURTESY OF NuWAVES LTD.



■ FILTERs are offered in both standard and custom models for RF applications.

that someone should have thought of it long ago. Such is Socket Sense™, from IDEATIVE Product Ventures (www.ideativeinc.com). You will have noticed by now that the average surge protector isn't equipped to handle bulky AC adapters, so perhaps half of your outlets go unused. But the Socket Sense version not only sets the sockets at a 45° angle to provide extra clearance, it expands from 13 to 18 in (33 to 46 cm) so that every one is actually usable. Well, duh! No more daisy-chaining under your desk! The units offer six sockets, 2160 J of surge protection, and six or 12 ft (1.8 to 3.6 m) power cords. The list price is \$29.99. **NV**

PHOTO COURTESY OF IDEATIVE.



■ The Socket Sense expanding surge protector.

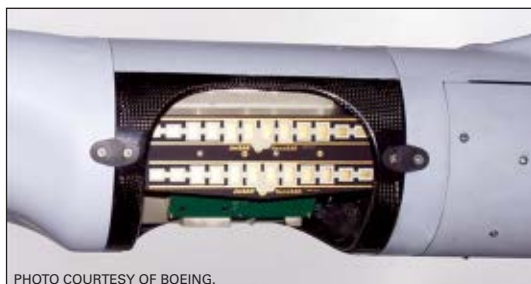


PHOTO COURTESY OF BOEING.

SURGE PROTECTOR FOR AC ADAPTERS

Every once in a while, someone comes up with a good idea that's so bonehead simple

■ The NanoSAR synthetic aperture radar, designed for use aboard the ScanEagle aircraft.

Amazing Devices

www.amazing1.com

See website for further descriptions

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STAMP APPLICATIONS

PUTTING THE SPOTLIGHT ON BASIC STAMP PROJECTS, HINTS & TIPS

■ BY JON WILLIAMS

PUTTING THE BRAKES TO IT

EVEN IF YOU'VE NEVER BEEN TO LOS ANGELES, chances are that you've heard of the 405 freeway. This infamous chunk of 10-lane hell extends from the San Fernando Valley south through the west side of Los Angeles, past LAX, and all the way down into Orange County where it reconnects with Interstate 5. The 405 spent some time in the news a few years ago for all the gun play associated with "road rage." As a Los Angeleno who frequently travels the 405, I smile at everybody — no matter how discourteous they might be; you never know who's having a really bad day. The bigger problem, though, is that in a sea of brake lights I have — far more times than I want to remember — found myself cringing as I hear the squeal of tires on the pavement behind me; usually someone on a cell phone that wasn't paying attention. Thankfully, I haven't been hit yet and I fully intend to keep it that way.

The problem with being stuck in traffic is that you are, in fact, stuck and there is no way to avoid being hit from behind by that person who's paying more attention to their phone conversation than the cars in front of them. On my long drive home from the Maker Faire in May, I noticed that the flashing lights of a police car in my peripheral vision immediately got my attention (no, the police car was not for me). So I started thinking ... there were a lot of lights in my rear view mirror, so why did I notice the police lights?

I believe the answer is simple: motion. Perhaps it's a remnant of the reptilian brain of our ancestors, but it seems that we notice motion first, then evaluate what that motion is and means second — this makes perfect sense considering the fight-or-flight response mechanism that has helped our species survive all these years. Quick detection of motion is valuable as there was a time we had to trek into the woods instead of Trader Joe's to get dinner supplies.

While retrieving my suitcase from the back of my SUV, I noticed something else: that the middle brake light housing in the rear window had a perfectly flat surface on which I could mount something. Hey, how about a panel of blinking lights to get the attention of the drivers behind me? My favorite TV creator, Joss Whedon (*Buffy*, *Angel*, *Firefly*), once said in an interview: "Blinky lights mean science." Well, for me, blinky lights mean a better chance of surviving the 405 without getting run into!

HARDWARE

The circuit is simple: an SX28 that drives 15 LEDs through ULN2x03s. The reason for the ULN2x03 is to provide enough current so that all LEDs can be on at the same time — at about 20 mA each, it's just too much to sink or source out of the SX without help. Also, this lets me re-use this circuit for other applications, even those that drive higher current devices (the ULN2803 can sink better than 150 mA per channel with all eight operating). I'm thinking I may re-visit my electronic Menorah project with small incandescent lamps this winter and this circuit will work perfectly for it.

1 shows the schematic for my "brake light buddy" — everything is as straightforward as you would imagine. You may be wondering why I went with 15 LEDs instead of 16. The reason is that I'm going to use bit 15 of the output data as a flag to mark the end of a sequence. If you modify the board, you might choose to simplify parts selection by using two ULN2803s instead of the combination as I have done — I keep both in stock for my control projects so the design as presented made sense for me.

One note about the circuit: JP1 is not intended to be moved; this is a solder-in selection. As this project is running LEDs, I'm using +5V from the regulator as the common voltage for the anodes. If you use this circuit to power valves or relays, you would probably choose a 12V external source and use Vin to run them.

FIRMWARE

This program is a simple sequencer that actually started out even simpler. In the beginning, I just read a four-position DIP switch to select a sequence and then jumped to a routine to handle it. Two things happened: 1) There is no way I need a selection of 16 sequences for a brake-light accessory. and 2) The LEDs I used are blindingly bright. What I ultimately decided to do was to use two of the DIP switches for the sequence selection and two for the LED brightness level. I also modified the sequence data to include step timing for that sequence instead of using a single global value as in the original program; this makes the sequence generation more dynamic, especially when two or more sequences are combined.

DATA STORAGE, SX/B STYLE

For those of us who started with the BASIC Stamp, we're used to the **EEPROM** (BS1) and **DATA** (BS2) directives that are used to store values in the Stamp's EEPROM. With SX/B, we have two directives: **DATA** (for bytes) and **WDATA** (for words). As with the BASIC Stamp, we can use **READ** to access these values. Unlike the

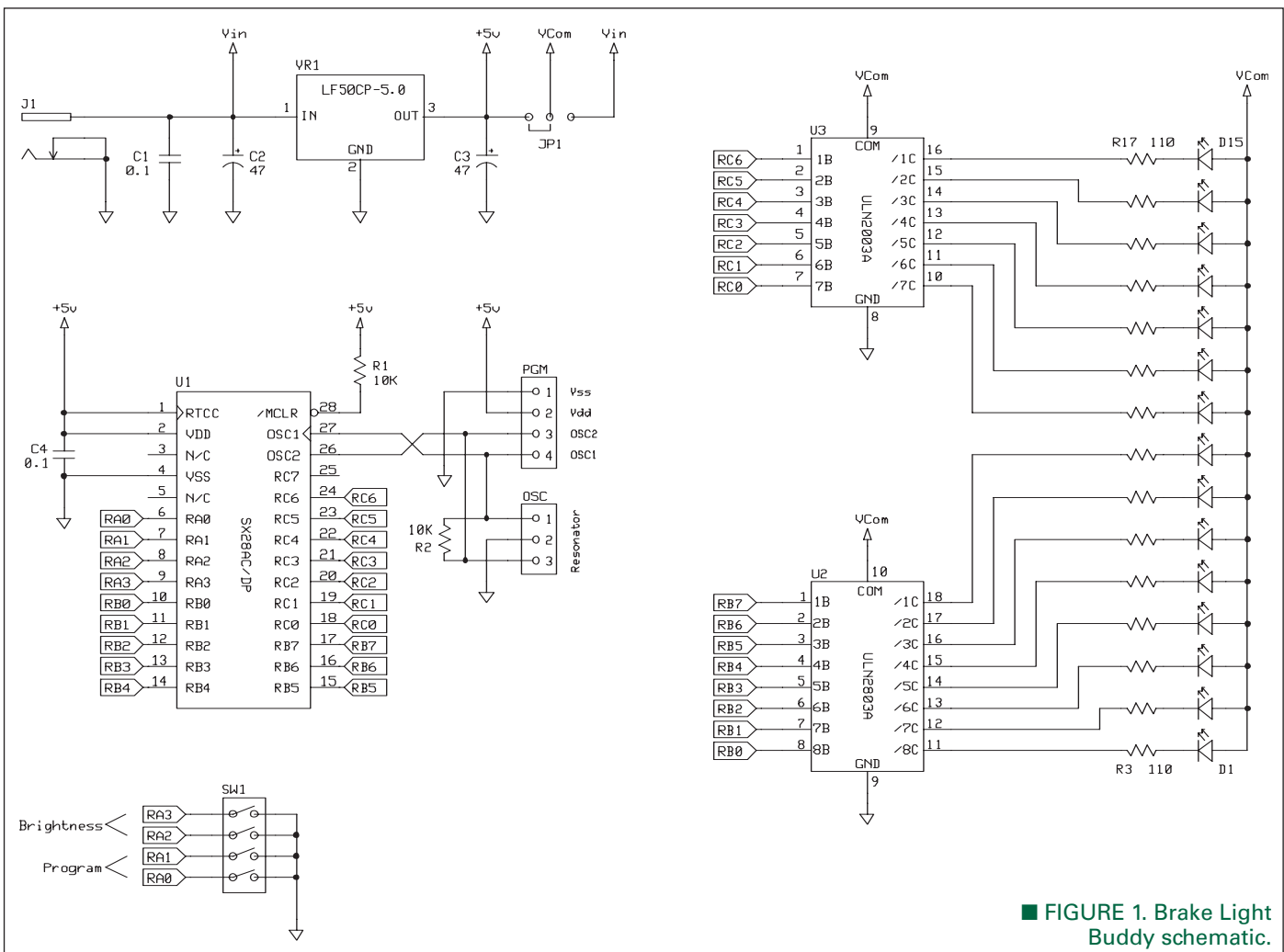
BASIC Stamp, however, there is no **WRITE** instruction in SX/B and once programmed, **DATA** and **WDATA** values cannot be modified.

The reason that we can modify **EEPROM** and **DATA** values in the BASIC Stamp is that these values are written into an external (of the processor) EEPROM. With the SX, however, these values are actually "burned" into the code space of the SX and this space cannot be modified at run time. You could, of course, add an external EEPROM to the SX (which is easy to do with SX/B's I²C instructions), should you need to store non-volatile values that can be changed.

In this program, I ended up using both **DATA** and **WDATA** to store an LED sequence — let's have a look.

Zig_Zag:

```
DATA 100
WDATA %0_0000000000000111
WDATA %0_000000000111000
WDATA %0_0000000111000000
WDATA %0_0001110000000000
WDATA %0_1110000000000000
WDATA %0_0001110000000000
WDATA %0_0000001110000000
WDATA %1_000000000111000
```



■ FIGURE 1. Brake Light Buddy schematic.



We start by using a label to name the sequence; this allows the compiler to resolve the label to an address that is used by the **READ** function to retrieve a table element. The first byte in the sequence, defined with **DATA**, is used as the timing (in milliseconds) for the sequence. What follows are the desired LED output patterns. As these values are words, we use **WDATA**. **WDATA** stores values Little Endian; you should know this if you are going to retrieve these values as bytes instead of as a word as we will do in this program.

One of the many things I like about SX/B is the flexibility with numeric formatting. SX/B allows an underscore character to be used in a number without any problems, so what I've done with the LED output patterns is separate bit 15 from the others. The reason for this is that the program will use bit 15 as a flag for the end of the sequence. As you can see, the last entry in the data table has a 1 in the bit 15 position. I like to use a built-in flag for projects like this as it allows the sequence to be modified without having to keep track of and editing the number of steps. If you wanted to use all 16 LEDs, then you can add a second **DATA** statement to the beginning of the sequence that defines the number of steps used — just remember to update this value when you modify the sequence (you'll also need to change the code that plays the sequence, but that's a one-time deal).

So, let's look at the code that plays the sequence. This is bundled into a subroutine that is called by passing the label of the sequence to play.

```
SUB PLAY_SEQUENCE
    tmpW2 = __WPARAM12

    READINC tmpW2, tmpB2
    DO
        READINC tmpW2, tmpW3
        IF invert = Yes THEN
            tmpW3 = tmpW3 ^ 0x7FFF
        ENDIF
        Display = tmpW3
        DELAY_MS tmpB2
    LOOP UNTIL tmpW3.15 = 1
ENDSUB
```

We start by capturing the address of the sequence to be played into tmpW2. The timing (in milliseconds) for each step in this sequence is retrieved using **READINC**, which is a special form of **READ**. **READINC** is very cool for code like this as it knows how many bytes to retrieve based on the size of the output variable(s) and then it automatically increments the address pointer by the appropriate value — again, based on the size of the output variable(s). What this means is that after reading the step timing value into tmpB2, the table pointer in tmpW2 is now pointing to the LED data for the first step in the sequence.

A **DO-LOOP** is used to play the sequence values and will terminate when bit 15 of the output pattern (which gets read into tmpW3) is set. At the top of this loop, **READINC** is used to retrieve a pattern from the table and

move it into tmpW3. Since tmpW3 is a word, **READINC** will increment the address (in tmpW2) by two after the call; this causes the address to be pointing to the next pattern in the **WDATA** table.

For a little extra flexibility, I added a global flag to invert the LED outputs. To do this, the raw value in tmpW3 gets XOR'd with 0x7FFF — this inverts all the bits in tmpW3 except our flag, bit 15. Note, too, that SX/B allows C-style numeric formatting and for hex values; I tend to do this to make my programs useful for those that will translate them to C. Whether it's modified or not, tmpW3 is moved into the LEDs which are ports RB and RC aliased as Display. A call to **DELAY_MS** holds the LEDs for the timing (in milliseconds) defined by the sequence.

Let's look at **DELAY_MS** for a moment as delays are an important aspect of this program and the fact that we're going to use an interrupt to control LED brightness (more on that in a moment) means that we can't simply use **PAUSE**.

```
SUB DELAY_MS
    IF __PARAMCNT = 1 THEN
        tmpW1 = __PARAM1
    ELSE
        tmpW1 = __WPARAM12
    ENDIF
    DO WHILE tmpW1 > 0
        tmpB1 = 25
        DO WHILE tmpB1 > 0
            \ CLRB isrFlag
            \ JNB isrFlag, @S
            \ DEC tmpB1
        LOOP
        DEC tmpW1
    LOOP
ENDSUB
```

Whether I'm using interrupts or not, I always use a subroutine called **DELAY_MS** as a replacement for **PAUSE**; without interrupts, this allows **PAUSE** to be compiled in one location and saves code space; with interrupts, I can fine-tune the routine based on the interrupt rate used. As I just stated, we will use interrupts in this program so the structure of **DELAY_MS** presented here will reflect that.

This routine starts by capturing the delay time — specified in milliseconds — to a word variable called tmpW1. If a byte is passed to the routine, it will show up in __PARAM1; if a word value is passed, it will show up in __WPARAM12. We can determine the type of value passed by examining __PARAMCNT; one for a byte, two for a word.

With the milliseconds now held in tmpW1, we will use that to control a **DO-LOOP** that has internal code that takes one millisecond to execute; the loop will decrement tmpW1 each time through and will terminate when tmpW1 reaches zero.

In this program, the interrupt is going to run 25,000 times per second so if we counted 25 interrupt cycles, we would have one millisecond. We get an assist on counting interrupt cycles by setting a flag inside the interrupt. To

count the ISR cycles, we start by setting tmpB1 to 25 then executing another **DO-LOOP** that waits for tmpB1 to hit zero. Inside this loop, we will clear isrFlag and then wait for it to be set again (which happens inside the interrupt). When the flag gets set, tmpB1 is decremented. These are done with inline assembly statements just to keep things as trim and zippy as possible. If you use this version DELAY_MS with a different interrupt rate, be sure to adjust the inner loop so that it runs for one millisecond.

Since I've been talking about the interrupt, let's have a look at it.

```
Mark_ISR:
    isrFlag = 1

PWM_Ctrl:
    acc = acc + brightness
    IF C = 1 THEN
        \ MODE $0F
        \ MOV !RB, #%00000000
        \ MOV !RC, #%00000000
    ELSE
        \ MODE $0F
        \ MOV !RB, #%11111111
        \ MOV !RC, #%11111111
    ENDIF

    RETURNINT
```

This code serves two purposes: 1) It sets isrFlag so we can use that for external timing as we saw with DELAY_MS above; and 2) It controls the LED brightness using a strategy normally employed for applying PWM to a single output.

The LED brightness is controlled adding the brightness setting into a running accumulator. When this accumulator rolls over (causing the Carry bit to be set), the LED output pins will be enabled; when there is no rollover, the LEDs are disabled by making those pins inputs. If we put a large value into the brightness variable, the rollover will take place more frequently, hence the LEDs will be on more of the time and therefore be brighter. By manipulating the TRIS registers of the LED pins, we are able to handle them all simultaneously. This is a useful trick and could be applied to the segment outputs of a seven-segment display project.

With all the support code in place, we can build the main line of the program. We'll start by reading the brightness settings from two of the bits of the DIP switch.

```
Start:
    brightness = %00111111
    brightness.6 = DMode.2
    brightness.7 = DMode.3
```

The first line sets the brightness to 63, or about 25%. The second line can add another 25% and the third can add 50%, based on the position of the DIP switches. The four-position DIP switch is attached to the RA port with all the pull-ups enabled, so an open switch will read as one. To dim the LEDs a bit, we can close one or both switches. My SUV has tinted glass in the back so I'm leaving them

open for maximum brightness.

The next step is to read the sequence selection and then run it.

```
Main:
    show = DMode & %00000011

    IF show = %11 THEN Display_Hold
    IF show = %10 THEN Ziggy
    IF show = %01 THEN Out_In
    IF show = %00 THEN Crazy_Flasher

Ziggy:
    invert = No
    FOR cycles = 1 TO 3
        PLAY_SEQUENCE Zig_Zag
    NEXT
    Display = %0000_0000_0000_1111
    DELAY_MS 100
    GOTO Display_Hold

Out_In:
    FOR cycles = 0 TO 1
        invert = cycles.0
        PLAY_SEQUENCE Explode
        PLAY_SEQUENCE Implode
    NEXT
    GOTO Display_Hold

Crazy_Flasher:
    invert = No
    FOR cycles = 1 TO 2
        PLAY_SEQUENCE Dual_Flash
    NEXT
    GOTO Display_Hold

Display_Hold:
    Display = %1111111111111111
    GOTO Display_Hold
```

The sequence bits are read from the DIP switch using a mask to isolate them from the brightness bits. From there, it is a simple matter of jumping to the appropriate handler. Inside each handler is a little loop to run a

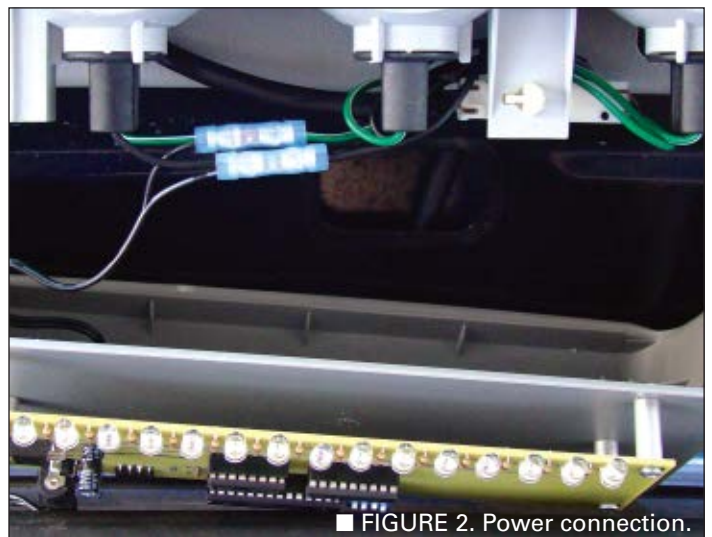


FIGURE 2. Power connection.

PARTS LIST

Item	Description	Supplier/Part No.
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▶ C2-C3	47 μ F	Mouser/647-UVR1V470MDD
▶ D1-D15	5 mm LED	Mouser/859-LTLR3SEK
▶ J1	2.1 mm barrel	Mouser/806-KLDX-0202-A
▶ OSC*	0.1" pin socket	Mouser/506-510-AG90D
▶ PCB	Printed circuit board	ExpressPCB.com
▶ PGM	0.1" R/A header	Mouser/517-5111TG
▶ R1	10K, 1/8W	Mouser/299-10K-RC
▶ R2*	10K, 1/8W	Mouser/299-10K-RC
▶ R3-R17	110, 1/8W	Mouser/299-110-RC
▶ Resonator*	4 MHz	Parallax/250-04050
▶ Resonator*	20 MHz	Parallax/250-02060
▶ Resonator*	50 MHz	Parallax/250-05060
▶ S1	28-pin DIP	Mouser/571-1-390261-9
▶ S2	18-pin DIP	Mouser/571-1-390261-5
▶ S3	16-pin DIP	Mouser/571-1-390261-4
▶ SW1	4 position DIP switch	Mouser/106-1204-EV
▶ U1	SX28	Parallax/SX28AC/DP
▶ U2	ULN2803A	Mouser/511-ULN2803A
▶ U3	ULN2003A	Mouser/511-ULN2003A
▶ VR1	LF50CP-5.0	Mouser/511-LF50CP

* = optional components



FIGURE 3. Installation.

As you can see, all of the handlers ultimately jump to the label Display_Hold which simply lights all the LEDs. Remember that the point of this project is to get a driver's attention, not to annoy him/her with non-stop blinking lights. Keep your movement patterns short and interesting and you're less likely to get honked at or [one-finger] saluted by the person behind you.

CONSTRUCTION AND INSTALLATION

While you could build this as a point-to-point wiring project, I just don't have that much patience anymore and the bumps in the road here in SoCal would likely shake that apart — a PCB is the best way to go. It didn't take long to whip up an ExpressPCB board for it, but note that the board is not the standard mini-board size and will cost more. That said, I grouped the ICs closely so that you could squeeze the project down to mini-board size (with fewer LEDs, of course) should you want to do that. Just one reminder on the board: The ULNs are active-low (the cathode connects to the ULN), so make sure you orient the LEDs in the board properly before soldering.

Physical installation will depend on your vehicle. As I stated earlier, my third brake light is in a housing that has a horizontal surface. I was able to remove the cover to



FIGURE 4. Update brake light.

sequence one or more times. You can see that the handler at Out_In combines two sequences and inverts them every other cycle; this is the pattern I tend to use most.

Ultra Low Power AM RF Receiver

ARX-433-ULC

03v
02.5v

ARX-433-ULC

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mount the board and tap into the brake light power. Figure 2 shows how I tapped into my brake lights using common butt splices; I scavenged a power plug from a dead wall wart for the connection to the board. Be very careful with this last step! You don't want to end up disabling your brake lights — this will definitely get you a ticket and could cause a safety issue. If in doubt, get help from a friend who is experienced in automotive electrical systems and always test everything very carefully before taking your car out onto the road. Figure 3 shows the assembly with the brake light cover reinstalled.

You can see in the photo of my completed board I omitted R2 and the resonator. Timing is not critical with this kind of project so the internal 4 MHz oscillator works just fine. If you use this board for a project that requires tighter timing or faster speed, add R2 and an appropriate resonator.

It is difficult to see in the photograph, but the LEDs I used are every bit as bright as the brake light that the project is attached to; the LEDs are clearly visible in daylight on a sunny southern California day. Figure 4 shows the LEDs lit when the brake light is operating.

BUILDER BEWARE

While I did check with a friend who knows more about California law than me — and he says it's okay — I do not, in fact, know if my little brake light add-on is legal to use, and you should check your local laws before putting it on the road. Other important points:

- 1) Integrate the device in your brake system — don't allow it to operate otherwise.
- 2) Make sure you can easily disable it should you be requested/ordered to do so.
- 3) Use only red LEDs — colored LEDs could be misconstrued as "official."
- 4) Never point the device forward as you could fool a driver in front of you and, perhaps, be accused of impersonating an official vehicle (which is against the law).

So, there you have it — a simple project that could prevent an

accident and turns out to have lots of useful bits that we can incorporate into other projects. What will you do with your "blinky" lights?

Until next time, Happy Stamping, SX/B-style! **NV**

JON WILLIAMS

jwilliams@efx-tek.com

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Digital Controlled FM Stereo Transmitters

- ✓ Rock stable PLL synthesized exciter
- ✓ Front panel digital control and display of all parameters!
- ✓ Professional metal case
- ✓ Super audio quality!
- ✓ 25mW kit and 1W export models!

For nearly a decade we've been the leader in hobbyist FM radio transmitters. When it became time for a new model, we started from the ground up! We told our engineers we wanted a new technology transmitter that would provide FM100 series quality without the advanced mixer features. They took it as a challenge and designed not one, but TWO transmitters!



The FM30 is designed using through-hole technology and components and is available only as a do-it-yourself kit, with a 25mW output very similar to our FM25 series. Then the engineers redesigned their brand-new design using surface mount technology (SMT) for a very special factory assembled and tested FM35WT version, with 1W output for our export-only market! Both are designed around an RF tight vinyl clad metal enclosure for noise free and interference free operation. All settings are done through the front panel digital control and LCD display! All settings are stored in non-volatile memory for future use.

Both the FM30 and FM35WT operate on 13.8 to 16VDC and include a 15VDC 110/220VAC plug in power supply. The stylish black anodized aluminum case measures 5.55"W x 6.45"D x 1.5"H. and is a great match to your other equipment. (Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.)

FM30B	Digital FM Stereo Transmitter Kit, 0-25mW	\$199.95
FM35BWT	Export Only Transmitter Assembled, 1W	\$299.95

Professional Synthesized Stereo FM Transmitter

- ✓ Fully synthesized 88-108 MHz for drift-free operation!
- ✓ Line level inputs and output!
- ✓ Simple DIP switch frequency setting

Priced like an inexpensive hobby transmitter but performs like a commercial unit! This unit is truly a cut above the rest, which probably explains why it is the most popular hobby transmitter around the world!

The FM25B features a PIC microprocessor for easy frequency programming without the need for lookup tables or complicated formulas! Frequency selection is done with simple DIP switches. The FM25B features a superb stereo generator providing you with amazingly good stereo separation to keep even the pickiest audiophile happy! Kit comes complete with case set, whip antenna, 120 VAC power adapter, & audio cable. SMT parts are factory preassembled! (Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body)

FM25B	Professional Synthesized FM Stereo Transmitter Kit	\$139.95
-------	--	----------

Tunable FM Stereo Transmitter

- ✓ Tunable throughout the FM band, 88-108 MHz!
- ✓ Settable pre-emphasis 50 or 75 µSec for worldwide operation
- ✓ Line level inputs with RCA connectors

The FM10A has plenty of power and is manually tunable across the entire band. The detailed manual covers theory, range, and FCC Rules & Regulations making it a favorite school and Scouting learning kit. Runs on an internal 9V battery, external power from 5 to 15 VDC, or an optional 120 VAC adapter. Learn all about FM stereo broadcasts with this simple kit. Includes matching case!

FM10C	Tunable FM Stereo Transmitter Kit	\$44.95
AC125	110VAC Power Supply for FM10C	\$9.95

Tru-Match FM Broadcast Antenna

We've been besieged with calls asking us where to get a good quality FM Broadcast antenna. Remember, matching your antenna to your transmitter is the single most important link in your transmitter setup - and a good antenna and match are the secret to getting maximum range.

When we say "match" we mean electrical impedance match... if the proper impedances are not maintained between transmitter and antenna, power is reflected away from the antenna and back into the transmitter! This can cause the final amplifier stage to be damaged, not to mention spurious signals and lousy range. Don't forget, there are three important factors in your broadcast range: antenna, antenna, and antenna! With the Tru-Match you'll get the most from your FM Broadcaster!

TM100	Tru-Match FM Broadcast Antenna Kit	\$69.95
-------	------------------------------------	---------

Professional FM Stereo Radio Station

- ✓ Built-in audio mixer!
- ✓ 2 line inputs, auto mic ducking!
- ✓ Dual LED bar graph meters
- ✓ Drift-free PLL synthesized operation
- ✓ Precision brick wall audio filter!
- ✓ 25mW kit and 1W export models!



The true professional workhorse of our FM Stereo transmitter line, the FM100B has become the transmitter of choice for both amateurs and professionals around the world. From the serious hobbyist to churches, drive-in theaters, colleges and schools, it continues to be the leader. Not just a transmitter, the FM100B is a fully functional radio station and provides everything but the audio input and antenna system.

This professional synthesized transmitter is adjustable directly from the front panel with a large LED digital readout of the operating frequency. Just enter the setup mode and set your frequency. Once selected and locked you are assured of a rock stable carrier with zero drift. The power output is continuously adjustable throughout the power range of the model selected. Audio quality is equally impressive. A precision active low-pass brick wall audio filter and peak level limiters give your signal maximum "punch" while preventing overmodulation. Two sets of stereo line level inputs are provided with front panel level control for both. Dual front panel LED bargraph meters provide left and right channel audio level metering. In addition to the line level inputs, there is a separate microphone input with a built-in mic mixer to control the level. Not enough? How about unattended microphone ducking! When enabled, the presence of mic audio automatically reduces and overrides the line level input! Just like the professional units at a fraction of the cost. The FM100B is truly a complete radio station!

(Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM100BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.)

FM100B	Super-Pro FM Stereo Radio Station Kit, 5uW-25mW	\$269.95
FM100BEX	High Power Version Kit, 5uW-1Watt Output	\$349.95
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Professional Synthesized AM Radio Transmitter

- ✓ Fully frequency synthesized, no frequency drift!
- ✓ Ideal for schools
- ✓ Microprocessor controlled
- ✓ Simple settings



Run your own professional sounding AM "Talk Radio" station! The AM25 operates anywhere within the standard AM broadcast band, and is easily set to any clear channel in your area.

It is widely used by schools - standard output is 100 mW, with range up to 1/4 mile, but is jumper settable for higher output where regulations allow. The PLL synthesized frequency is easily set with dip-switches and is rock solid without any drift, just like our FM25B. The transmitter accepts line level input from CD players, tape decks, etc. Includes matching case & knob set and AC power supply! (Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body)

AM25	Professional Synthesized AM Radio Transmitter Kit	\$99.95
------	---	---------

Tunable AM Radio Transmitter

- ✓ Tunes the entire 550-1600 KHz AM band!
- ✓ 100 mW output, operates on 9-12 VDC
- ✓ Easy to assemble one evening kit!
- ✓ Line level input with RCA connector



A great first kit, and a really neat AM radio transmitter! Tunable throughout the entire AM broadcast band. 100 mW output for great range! Learn kit building and radio theory and at the same time get on the air with your own "station"! The AM1C has also been used by Scout camps, churches, schools, and other organizations to provide easy, low cost communications at events, meetings and much more. Includes matching case!

AM1C	Tunable AM Radio Transmitter Kit	\$34.95
AC125	110VAC Power Supply for AM1C	\$9.95



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- ✓ DDS and SMT technology!
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- ✓ 0 to 10V peak to peak output level
- ✓ Sine, Square, or Triangle waveform

Following our world famous SG550, we are proud to introduce the SG560, the next generation signal generator!



To begin with we increased the frequency range all the way up to 5MHz and all the way down to 0Hz (yes, we mean zero...or DC!) in continuous 0.1Hz steps across the entire range! Then we gave it a variable output level all the way up to 10V peak to peak in either Sine, Square, or Triangle waveforms! You can also provide a DC offset to the output to recreate TTL, 4000 series logic levels, low voltage logic levels, AC waveforms with a DC component, or just plain AC signals!

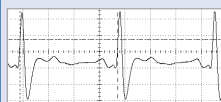
SMT and DDS technology is used throughout the SG560 for ultimate performance and reliability. If you're looking for a lab quality sig gen at a super hobbyist price, the brand new SG560 fits the bill...and a whole lot more!

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- ✓ Re-usable sensors included!
- ✓ Monitor output for your scope
- ✓ Simple & safe 9V battery operation



Enjoy learning about the inner workings of the heart while at the same time covering the stage-by-stage electronic circuit theory used in the kit to monitor it.



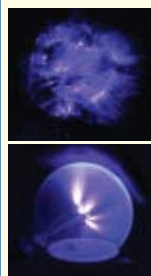
The three probe wire pick-ups allow for easy application and experimentation without the cumbersome harness normally associated with ECG monitors. The fully adjustable gain control on the front panel allows the user to custom tune the differential signal picked up by the probes giving you a perfect reading every time! Multiple "beat" indicators include a bright front panel LED that flashes with each heart beat, an adjustable audio output to hear the beat, and of course, the monitor output to view on a scope, just like in the ER! Operates on a standard (and safe) 9VDC battery. Includes matching case for a great finished look. The ECG1 has become one of our most popular kits with hundreds and hundreds of customers wanting to get "Heart Smart"!

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Plasma Generator

- ✓ Generates 2" sparks to a handheld screwdriver!
- ✓ Light fluorescent tubes without wires!
- ✓ Build your own plasma balls!
- ✓ Generate up to 25kV @ 20KHz from a solid state circuit!



This popular kit was conceived by one of our engineers who likes to play with things that can generate large, loud sparks, and other frightening devices! The result... the PG13 Plasma Generator designed to provide a startling display of high voltage!

It produces stunning lighting displays, drawing big sparks, to perform lots of high voltage experiments. In the picture, we took a regular clear "Decora" style light bulb and connected it to the PG13 - WOW! A storm of sparks, light tracers and plasma filled the bulb. Holding your hand on the bulb doesn't hurt a bit and you can control the discharge! It can also be used for powering other experiments; let your imagination be your guide! Operates on 16VAC/VDC for maximum output. Can also be run from 5-16VAC/VDC to reduce the output voltage.

PG13 Plasma Generator Kit
PS21 110VAC input, 16VAC output power supply

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\$19.95



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- ✓ Test for preliminary emissions status!



No comments are necessary this summer about the cost of gas! Last month's ad said approaching 4 bucks. Look what happened in a month, now it's approaching 5 bucks a gallon! At that price it's more important than ever to make sure your vehicle is in tip-top shape for the most economical performance possible.

Did you know old spark plugs can reduce fuel economy by 30%? It gets worse... a bad oxygen sensor cuts it by 40%! And that relates to a lot of extra gas and at 5 bucks a gallon, just do the math... That's a LOT of money!

With the CarChip Pro you'll have complete access to all your vehicles diagnostic data at your fingertips! Sort miles by type (business, personal or driver), set thresholds for alarms, calculate gas mileage, log extreme acceleration and braking, speed, engine parameters, and a whole lot more! And as you know, extreme acceleration does not equal fuel economy! Find out who's driving your vehicle like a race car...and deal with it!

The CarChip Pro is great if you have a new driver in the family. Easily monitor their performance and let them gain additional privileges with a good driving record! You have the proof!

No more taking your car in to see why your "check engine" light is on. The CarChip Pro will automatically provide the trouble codes and allow you to reset it! CarChip Pro includes storage for up to 300 hours of driving data! If you're unfortunate enough to be involved in an accident, it even records all the vehicle's parameters for the last critical 20 seconds of operation! Includes USB cable, software and complete instructions.

8226 Davis OBDII CarChip Pro Data Logger

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USB Experimenter's Interface Board

Get hands-on experience developing USB interfaces! 5 digital inputs, 8 digital outputs, 2 analog I/O's! Includes diagnostic software and DLL for use with Windows based systems. You can also write custom Windows applications in Delphi VB, C++, or any other 32 bit Windows development tool that supports calls to a DLL. The mystery is solved with this kit!



K8055 USB Experimenters Kit

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PIC Programmer & Experimenter

Not just a PIC programmer but a great test and experimenter's board to boot! Supports 8, 14, 18, and 28 pin PIC's. Create code in any ASCII word processor or Microchip's MPLAB development package and write it directly to the PIC. Separate sockets eliminate the need to patch a ZIF socket. Includes test and diagnostic software and a PIC16F627 Micro!



K8048 PIC Programmer & Experimenter Kit

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Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ Solar Project Circuit
- ✓ Voltage Reduction
- ✓ Single Chip FM Receiver

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:

Q&A@nutsvolts.com

15 MINUTE TIMER

Q I am a ham radio operator who does a lot of remote site operations here in Alaska on the various Oscar satellites. This is accomplished using an HT and the typical Arrow handheld satellite dual-band beam antenna. Recently, I installed an AR² UHF preamp on one side of the handle which is powered by a nine volt battery clipped on the other side.

Unfortunately, I have been killing a lot of nine volt batteries by forgetting to disconnect the snap connector from the battery top after a satellite pass. Rather than simply install the battery in a small box with an LED and a switch — which I would also probably forget to flip — instead I would like to use a pushbutton timer to start the preamp and then later automatically switch it off. Since no LEO pass is

longer than 15 minutes, the push-button should pass the voltage to the preamp and light the LED for that period of time, and then drop to a very low or nonexistent current resting state until the next button push. The AR² preamp will work satisfactorily down to around 7 VDC and draws approximately 17 mA while in service. Do you have any ideas for a circuit that could be breadboarded on a very small piece of perfboard and installed in the nine volt battery box to accomplish these goals? Thanks for your assistance.

— Craig Bledsoe, KL4E

A A microprocessor is the best option here and it is simple enough that even I can do it. I chose the PIC12F675 because it is an eight-pin device, and because I have some. It has an A/D converter that I am not using, so the PIC12F629 could be used; it is the

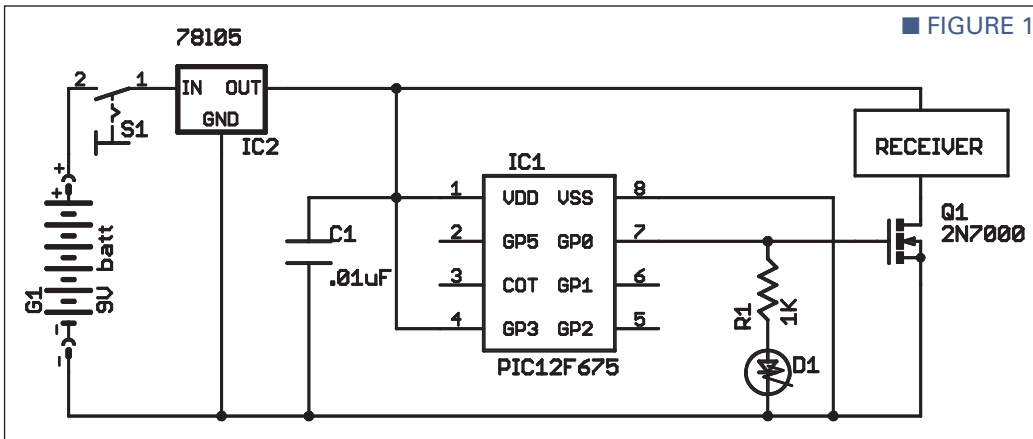
same device without the A/D converter. This micro has an internal oscillator and needs no external components to work. A five volt regulator is needed to operate from a nine volt battery and an FET switch turns the receiver on and off (see Figure 1). The program is in Figure 2; I tried to have it wake from sleep with an interrupt but could not make it work in a reasonable time, so you have to turn power off and on to recycle the timer.

TIMEBASE FOR RADAR CIRCUIT

Q Can you please check this circuit out (Figure 3)? It's for a project I am working on. It uses a 555 as the main time base, with a 2N3906 as a constant current source, and a LM311 as a pulse grabber that gives a narrow negative going pulse for the transmitting pulse. The 358 is an integrator that gives a sawtooth for the receiving pulse; both of which are displayed on a scope. If there are any flaws in it, please let me know.

— Craig Kendrick Sellen

A I like your variable duty cycle circuit, using D1 and D2 (R2 and R3 are a pot in your circuit, but that does not exist in LTSPICE). I



would put a diode in series with R6 to compensate the base-emitter diode of Q1, and you are right — R4 is not needed. There is a problem with IC2A, and I am sure you are going to slap your head when I tell you: the integrator wants to go negative but can't because there is no negative supply. The problem with IC2B is that it is an open loop op-amp with positive input; the output is just going to hang high. I think what you are trying to generate is a horizontal sweep signal that starts at zero and has fast return. The problem with IC3 is that the positive input is too close to the positive supply. The specification calls for a two volt difference and two diodes are only 1.2 volts. When the 555 output goes negative, C4 is discharged through D6 and when the output goes positive, the input to IC3 is lifted. But you have to keep in mind that the output of the 555 can only go within three volts of the positive supply and the input of IC3 is starting from -0.5 volts, so the bias on the positive input of IC3 should be no higher than four volts below the positive supply. The feedback to reset (pin 4) will make the output pulse very narrow, if that is what you want. I don't understand the purpose of D3 or the reason for R13.

I didn't realize it until I simulated the circuit, but since the 555 starts with a positive pulse, feeding the comparator back to reset results in continuous resets — you can't do that.

I have modified your circuit as in Figure 4. Since you want a narrow positive pulse to the receiver, turn the comparator output around by

```

*****
'* Name      : 15 Minute Timer.BAS
'* Author    : Russ Kincaid
'*
'* Date      : 4/12/2008
'* Version   : 1.0
'* Notes     : Power up starts the time and turns on a FET
'*           : switch. After 15 minutes, the FET switch is
'*           : is turned off and the micro goes to sleep. You
'*           : must turn power off then on to start the timer
'*           : again.
'*           :
*****
REM device = 12F675
CMCON = 7          ' SETS DIGITAL MODE
ANSEL = 0          ' GPIO.0 TO GPIO.3 SET AS DIGITAL
TRISIO = %00001000 ' Master clear as input
VRCON.7 = 0       ' TURN OFF VOLTAGE REFERENCE
INTCON = 0        ' No interrupt
N VAR WORD        ' VARIABLE N DEFINED
DEFINE OSCAL_1K 1  ' TO SAVE OSCILLATOR CALIBRATION
*****

HIGH GPIO.0      ' Turn on FET
FOR N = 1 TO 900 ' 15 minute timer
PAUSE 1000
NEXT N
LOW GPIO.0       ' TURN OFF FET
SLEEP 1         ' WDT is turned off so I think it never wakes

END
    
```

FIGURE 2

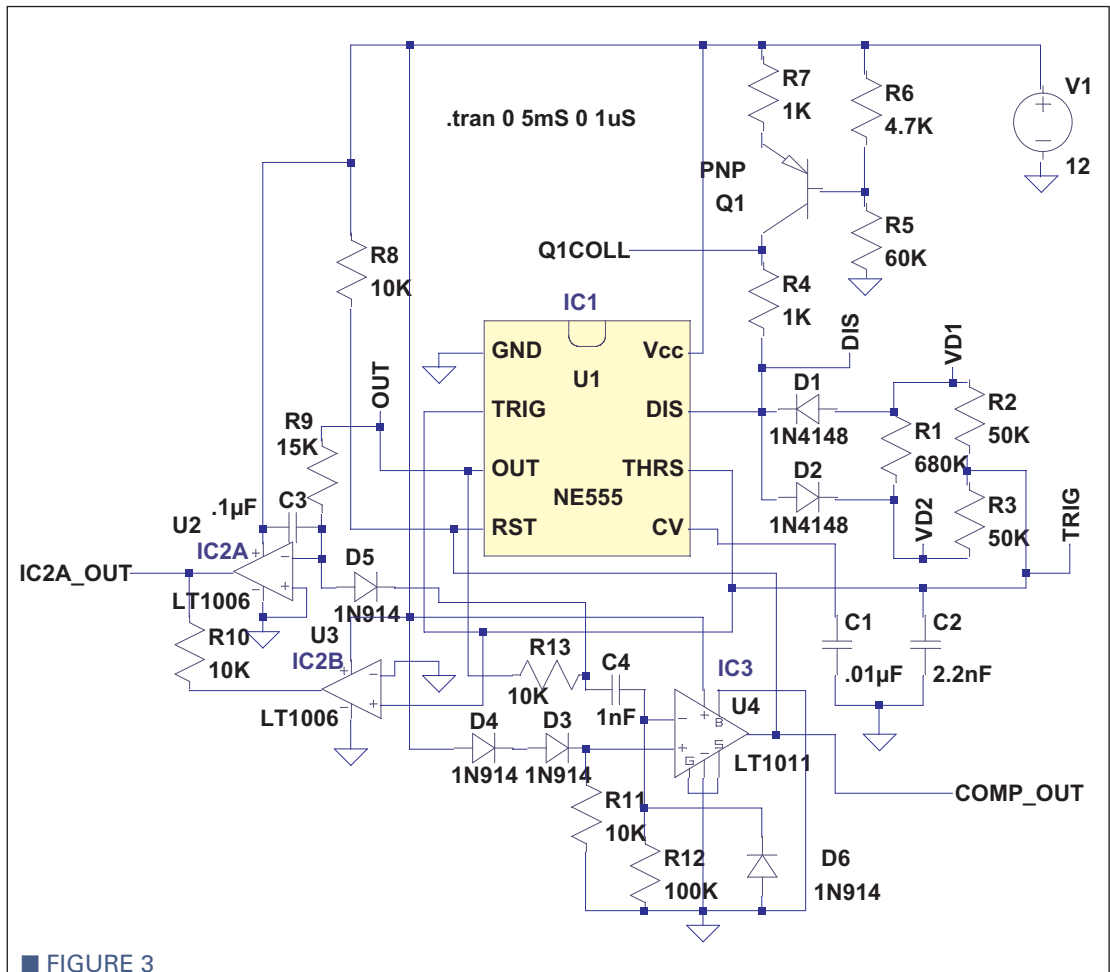
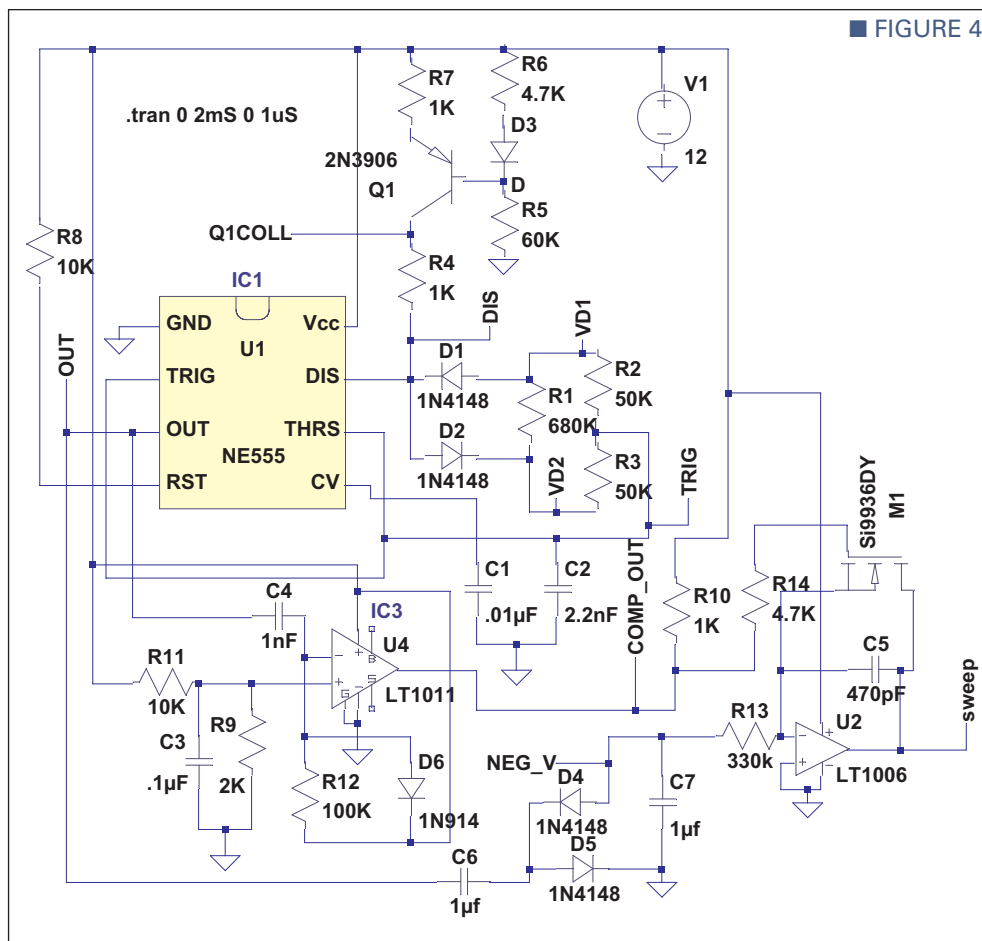


FIGURE 3

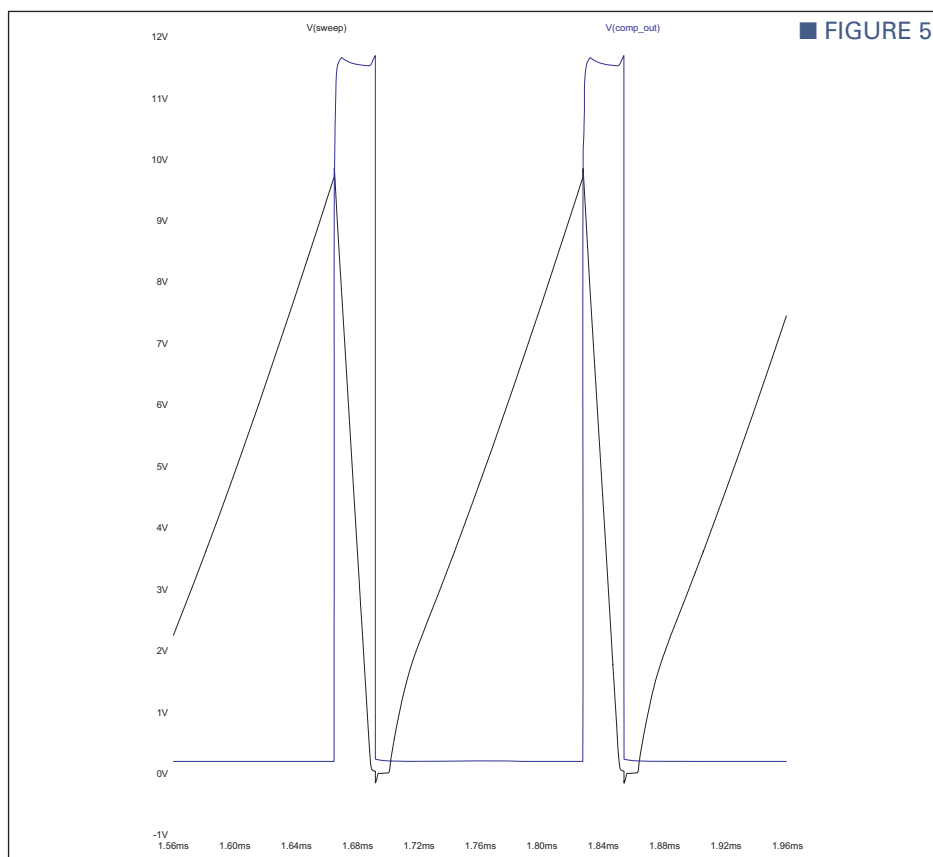


connecting R12, D6 to the positive supply. The sweep signal is generated by the U2 circuit. A negative input is needed to make the integrator go positive, so I rectified some of the 555 output with D4 and D5; storing the charge in C7. The voltage is about -11 VDC. The positive pulse from the comparator turns on the MOSFET, M1, which discharges the integrator capacitor, C5. I adjusted the pulse width by varying R9 such that the sweep just goes to zero. If you want a narrower pulse, use the comparator output to trigger another 555. For a negative pulse, use a CMOS inverter. Figure 5 is the comparator output and sweep waveforms.

SINGLE CHIP FM RECEIVER

Q I would like the IC number for building an FM (88-108 MHz) receiver using a small number of parts. Can you help me?

— Bill Tooley



A These URLs will give you much info about single chip FM receivers. The TDA7000 is no longer in production but ICs are available on eBay.

<http://braincambre500.freesevers.com/acameo.htm>

**[www.users.bigpond.com/cool386/
tda7000/tda7000.html](http://www.users.bigpond.com/cool386/tda7000/tda7000.html)**

**www.nxp.com/acrobat_download/
datasheets/SA647_3.pdf**

www.nxp.com/acrobat_download/datasheets/TDA7000_CNV_2.pdf

SOLAR PROJECT CIRCUIT

Q As a “charter” lifetime subscriber to *Nuts & Volts*, I look forward to every issue and especially the

construction projects. I have recently become interested in solar powered projects to use around the house. I currently have two solar-powered fountains (45 watt array with storage battery and charge controller) and a solar-powered web cam (wireless 802.11b using a 20 watt panel, storage battery, and charge controller). My problem is that in both cases, I want to shut down the load when evening falls. No need to power the camera or fountains in the dark. Also, this would keep the battery from discharging overnight and having to recharge for a few hours before my items come back to life. Finding circuits to turn things on at night is not a problem. I need a circuit to turn a load off. I know I could always "cheat" and use the "on at night" circuit to power a relay to turn my load off, but this would waste precious power. Do you have a relatively simple circuit that could be used to switch these loads (fountains are both 12 VDC, 2A each while the camera is 12 VDC 1.5 A). Any suggestions would be appreciated. Also, do you think you might write an article on "homebrew" solar projects? The recent article on the "whole house" solar system was great, but there are so many smaller applications (such as my two projects) that can be built rather inexpensively. Thanks for your help.

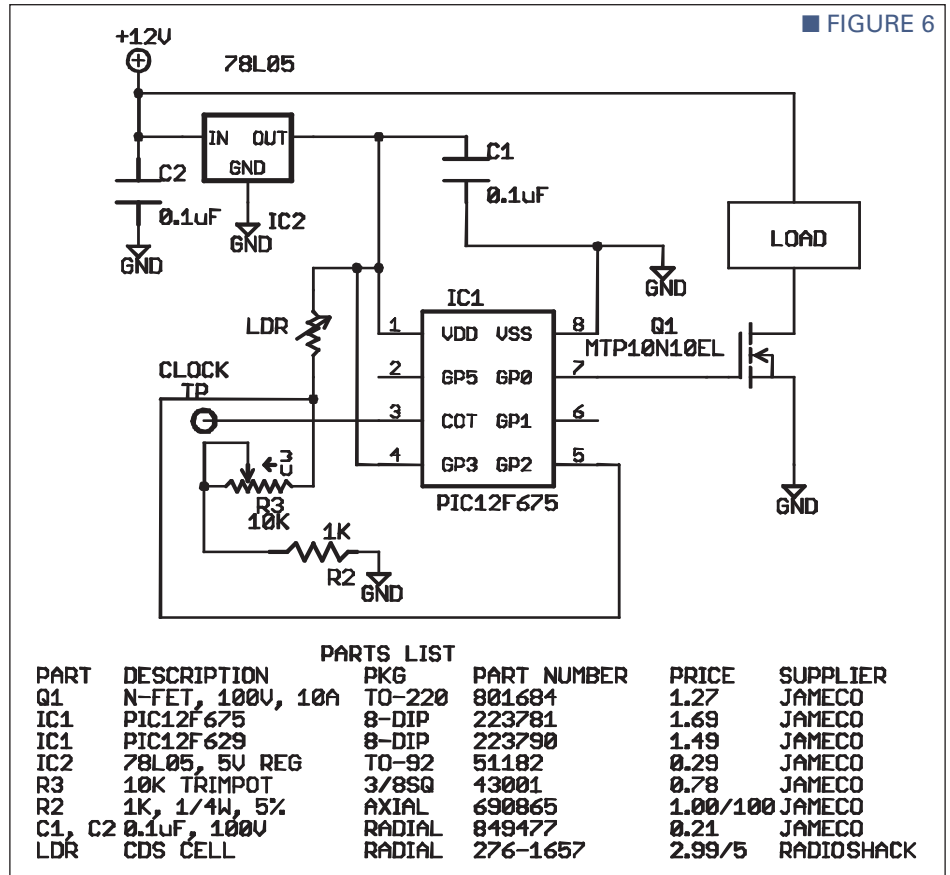
— Mark Albanese

A My first thought was to use a MOSFET and cadmium sulfide cell. Simple, but the slow turn on and off would cause a lot of power dissipation in the MOSFET and the motors might not like it either. Therefore, I went with the ubiquitous microprocessor because it will switch fast. The schematic is Figure 6. The light-dependent resistor (LDR) reduces as the day gets lighter. When the voltage at pin 5 is greater than the logic threshold, the program skips the dark routine and turns on the MOSFET switch. See the program in Figure 7. When it is dark, the program jumps to the dark routine, turns the transistor off, and goes to sleep. When the voltage at pin 5 exceeds the logic

threshold again, the micro wakes up and the program starts. The sleep time current drain is about 100 microamps. The GP2 input is a Schmitt trigger, so

there is considerable difference between light and dark and there is no problem of it switching on and off at sunup and sundown. The

■ FIGURE 6



```

*      Notes      :Daylight starts the program running, to turn the *
* *              :power on. Dark turns the power off and puts the *
* *              :micro to sleep. Daylight wakes the micro. *
* *              :The 12F629 can also be used but you have to remove *
* *              :the ANSEL statement or the compiler will balk. *
* *****

REM DEVICE = 12F675
CMCON = 7          'SETS DIGITAL MODE
ANSEL = 0          'GPIO.0 TO GPIO.3 SET AS DIGITAL
TRISIO = %00001100 'MASTER CLEAR & INTERRUPT AS INPUT
VRCON.7 = 0        'TURN OFF VOLTAGE REFERENCE
INTCON = %10011000 'GLOBAL & GP2 INT.,PORT CHANGE INT ENABLED
        IOC = %00000100 'GPIO.2 INTERRUPT ON CHANGE ENABLED
DEFINE OSCCAL_1K 1  'TO SAVE OSCILLATOR CALIBRATION
* *****

START:

        IF GPIO.2 = 0 THEN DARK
HIGH GPIO.0        'TURN ON TRANSISTOR SWITCH
GOTO START

DARK:

        LOW GPIO.0  'TURN OFF TRANSISTOR SWITCH
INTCON.1 = 0        'CLEAR INTERRUPT FLAG
INTCON.0 = 0        'CLEAR GPIF FLAG
ON INTERRUPT GOTO START
SLEEP 1             'SINCE WDT IS OFF, NEVER WAKES
RESUME
END

```

■ FIGURE 7

sensitivity is adjustable with R3 to compensate for light pollution. If light pollution is bad, you may have to put

the LDR in a tube pointed at the sky. The RadioShack CdS cells are an assortment of five. I used one of the

large ones but any should work. If any reader wants to build this circuit and does not have access to a

MAILBAG

Dear Russell,

Your column is the first thing I read. Even before you took over, I saw a lot of answers from you. Very good answers — in fact, you answered one for me! The question in the January '08 issue, on pages 26 and 27 about a mail box timer schematic was written by Anonymous.

I think my mail box timer may be an easier solution. It has worked for 12 years and I expect it will last some more (Figure 8). It makes no difference if the mail box door is left open or closed; a battery lasts a long time, almost shelf life. A micro switch mounted under the mail box door operates the circuit.

— William D. McMurray

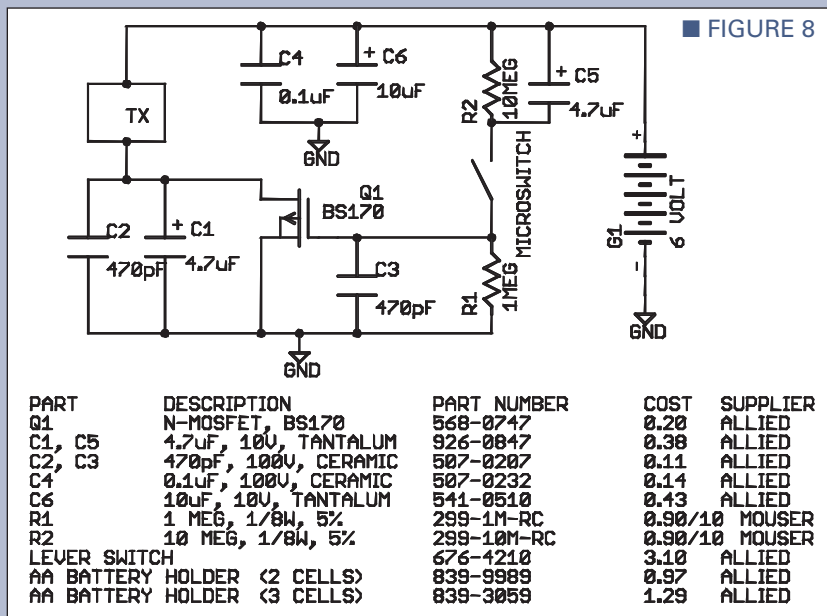
Response: Thanks for sending your circuit; it is simple and effective. Q1 stays turned on while C5 charges, until the gate voltage falls below the threshold. If the mail box door is left open, the 11 meg resistor across the battery is minimal drain. I took the liberty of creating a parts list and adding it to the schematic, although I imagine that you used what was available in your junk box.

Dear Russell,

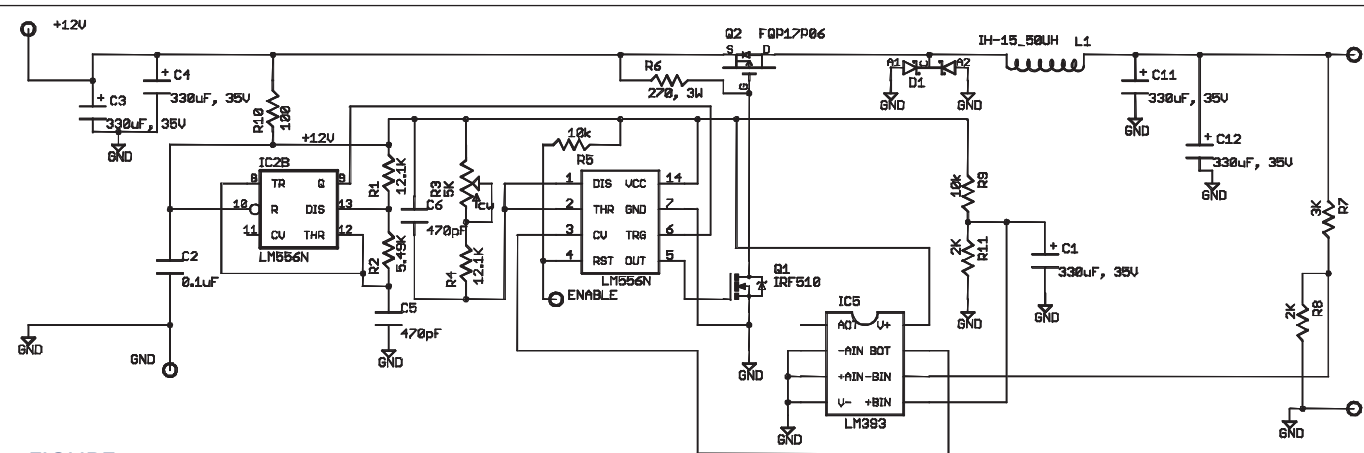
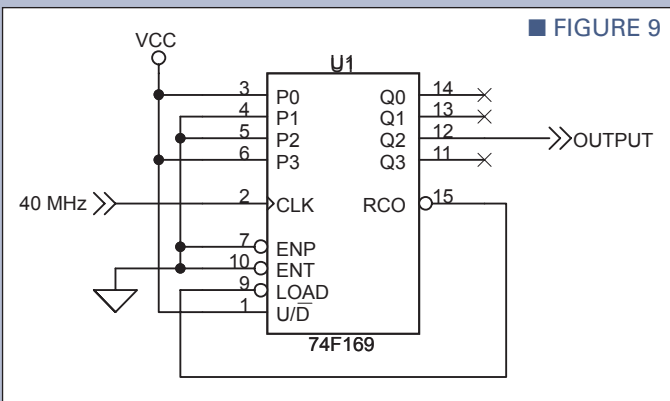
The answer to the question about dividing by 7 is incorrect. The circuit as-is divides by 8. Also, the two 2 input nand gates can glitch and set or clear the RS flipflop at the wrong time. See the attached circuit (Figure 9) for a much simpler circuit.

— Geoff Probert

Response: Thanks for the feedback. You forced me to go through the timing diagram in excruciating detail. I should have done that in the beginning, but thought I



could do it in my head; I was wrong. Your solution (load 9 and count to 16) does divide by 7 and the Q2 output is 4:3 mark/space as I wanted. Mea culpa once again.



programmer, I can supply a programmed 12F675 for \$5, shipping included in the lower 48 states. Contact me at russlk@yahoo.com, or order from the online store.

VOLTAGE REDUCTION

Q How can I bring 12 volts DC (auto battery) down to five volts DC at one amp?

— Richard

A The quickest solution is to use a L7805 voltage regulator IC which is rated at 1.5 amps. The datasheet recommends 0.33 μ F input capacitance and 0.1 μ F output capacitance. The datasheet at www.st.com/stonline/books/pdf/docs/2143.pdf will show you how to hook it up. The down side is that you will be throwing away seven watts of power all the time to get five watts out and you will need a heatsink on

5V PWM POWER SUPPLY PARTS LIST

FIGURE 11

PART	DESCRIPTION	MOUSER P/N
■ R1, R4	12.1K, 1%, 1/8W	290-12.1K-RC
■ R2	5.49K, 1%, 1/8W	290-5.49K-RC
■ R3	5K pot, 3 mm, SMD	652-TC33X-2-502E
■ R5, R9	10K, 1%, 1/8W	290-10K-RC
■ R6*	270 ohms, 5%, 3W	283-270-RC
■ R7	3.0K, 1%, 1/8W	290-3.0K-RC
■ R8, R11	2.0K, 1%, 1/8W	290-2.0K-RC
■ C2	0.1 μ F, 50V, X7R	140-CC502B104K-RC
■ C3, C4, C11, C12*	330 μ F, 25V, 10%	140-ESRL25V330-RC
■ C5, C6	470 pF, 5%, NPO	80-C315C471J1G
■ IC2*	LM556 Dual Timer	511-NE556
■ IC5	LM393 Comparator	511-LM393DT
■ Q1*	NMOS, 50V, 2A, TO-220	844-IRF510PBF
■ Q2*	PMOS, 30V, 15A, TO-220	512-FQP17P06_Q
■ D1*	SCHOTTKY, 10A, 50V	844-10CTQ150PBF
■ L1*	50 μ H, 10A	70-IH15BQ500K

* Denotes thru-hole part, otherwise surface-mount

the IC rated over seven watts. For the heatsink, I recommend Mouser part number 532-531202B00; \$1.19 each. Mouser also has the the L7805CV voltage regulator in TO-220; part number 511-L7805CV, \$0.48.

The other solution — more expensive but saves power — is a

PWM regulator. I designed a similar regulator for the June issue and have modified it for your requirements. The schematic is Figure 10. I included the parts list (Figure 11) modified from the June list. The efficiency should be 90% or better so you won't need a heatsink with a one amp load. **NV**

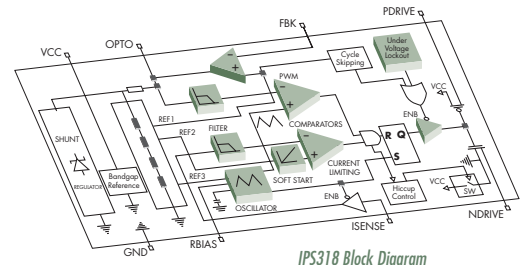
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- Automotive
- Mobile devices
- Laptops and PDAs
- Utility meters
- Battery chargers



IPS318 Block Diagram

Ordering Information

Ordering PN	Subgroup	Description	Temp. Range (2)	Package	Packing Type	Packing Qty
IPS315 (1)-D-G-LF	Controller	IPS15 with 7.2V V _{cc} , Direct FB	C, A	8-Pin DIP	Tube	50
IPS315 (1)-S-O-G-LF	Controller	IPS15 with 7.2V V _{cc} , Direct FB	C, A	8-Pin SOIC	Tube	98
IPS315 (1)-S-O-G-LF-TR	Controller	IPS15 with 7.2V V _{cc} , Direct FB	C, A	8-Pin SOIC	13" T&R	2500
IPS315H (1)-D-G-LF	Controller	IPS15 with 7.2V V _{cc} , Direct FB, Hiccup OCP	C, A	8-Pin DIP	Tube	50
IPS315H (1)-S-O-G-LF	Controller	IPS15 with 7.2V V _{cc} , Direct FB, Hiccup OCP	C, A	8-Pin SOIC	Tube	98
IPS315H (1)-S-O-G-LF-TR	Controller	IPS15 with 7.2V V _{cc} , Direct FB, Hiccup OCP	C, A	8-Pin SOIC	13" T&R	2500
IPS318 (1)-D-G-LF	Controller	IPS315H + Cycle Skipping	C, A	8-Pin DIP	Tube	50
IPS318 (1)-S-O-G-LF	Controller	IPS315H + Cycle Skipping	C, A	8-Pin SOIC	Tube	98
IPS318 (1)-S-O-G-LF-TR	Controller	IPS315H + Cycle Skipping	C, A	8-Pin SOIC	13" T&R	2500

(1) Place holder in part number for Temperature Range designator.
(2) C: Commercial; A: Automotive



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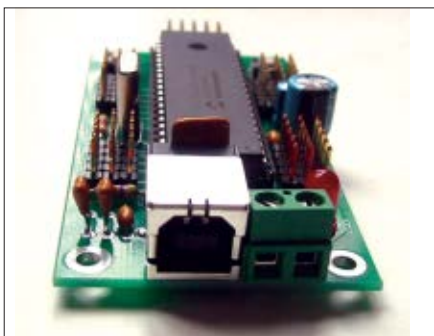
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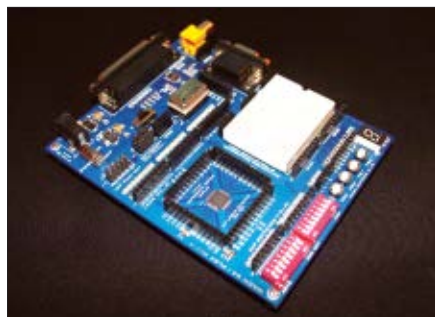
Complete with USB interface, 50 Hz refresh rate, and fully independent adjustable pulse widths, the 25 servo controller was designed with the hobbyist, as well as the professional, in mind. Instead of the standard 1-2 ms pulse widths, the 25 servo controller from Endurance R/C allows pulses of .5-2.5 ms to be generated, allowing for an extended movement range of some servos.

With its isolated power connection system, the servo and controller electronics power systems are kept completely separate allowing 5V, 6V, and even 9V or higher servos to operate at their proper voltage. This is a useful feature for all the new high torque robotic servos on the market.

Need more than 25 channels? With the USB interface, adding more channels is simple. The 25 servo controller is fully backwards compatible with all previous software and examples. In addition, the new controller is Windows XP and Vista compatible. Sample software, examples, videos, and API documentation can all be found at the website.

For more information, contact:
Endurance R/C
Web: www.endurance-rc.com

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What's a CPLD? CPLDs are chips that are internally constructed of an array or matrix of programmable logic units or blocks. Each cell can perform various logic functions. The power of CPLDs is that with a software based tool you can write "code" that is compiled into a hardware description that is then downloaded and Flashed into the CPLD, changing its behavior to your exact specifications. By mastering this technology, you can develop your own chips that run at very high speeds, as well as design very complex systems that would be impossible with discrete TTL chips.

CPLDs are a great starting point for those interested in programmable logic technology and allow you to seamlessly move into their bigger brothers — Field Programmable Gate Arrays (FPGAs) — when you're ready. The new MACH64 from Nurve Networks kit is two kits in one:

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KC-5460 \$58.00 + postage & packing

This PIC-based unit uses a pressure sensor to monitor water level and will display tank level via an RGB LED at the press of a button. The kit can be expanded to include and optional wireless remote display panel that can monitor up to ten separate tanks (KC-5461) or you can add a wireless remote controlled mains power switch (KC-5462) to control remote water pumps. Kit includes electronic components, case, screen printed PCB and pressure sensor.



Telemetry Base Station for Water Tank Level Meter

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This Base Station is used with the telemetry version of the KC-5460 water tank level meter. It has an inbuilt 433MHz wireless receiver and can handle data transmissions from up to 10 level meters and display the results on a 2-line 32-character LCD module. Kit includes silk screened PCB, case, electronic components, receiver module and the RF transmitter upgrade for one tank level meter. Remote electric pump control option available. Requires 9-12VDC 100mA plugpack.



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- Power figures applicable when described power supply is used.



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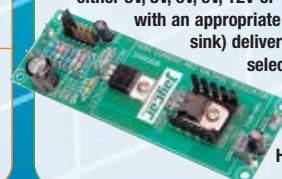


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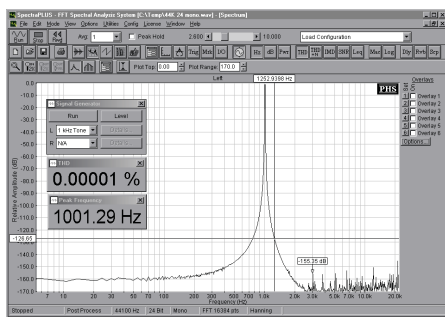
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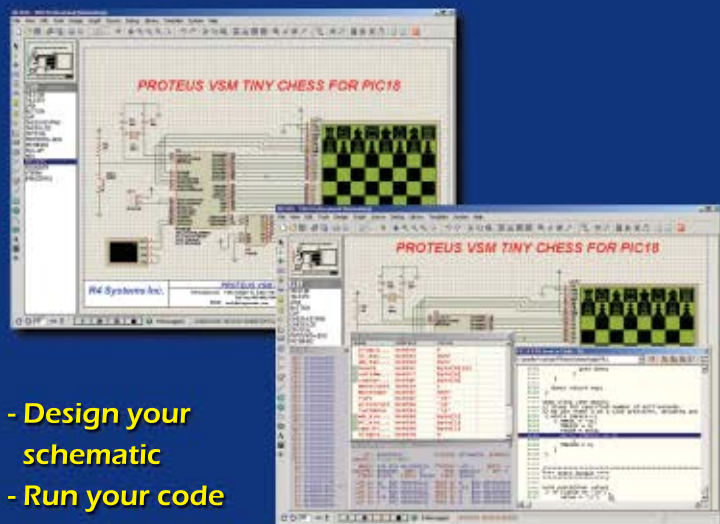
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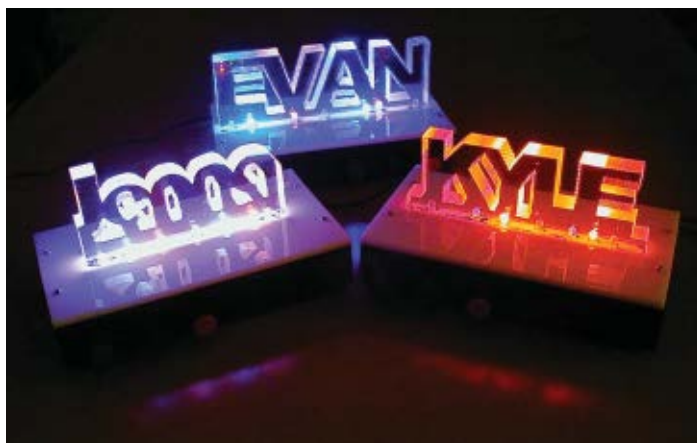
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BUILD THE ILLUMINAME

BY JULES RYCKEBUSCH

Light Emitting Diodes — or LEDs — have fascinated me since I was a teenager. I have built many projects over the years with them, usually involving blinking or sequenced chase lights using 555 timers and 4017-decade counters. Over the past few years, both the intensity and available colors of commercial LEDs

have drastically improved. This includes blue ones that, when combined with red and green LEDs, can make up a pixel of an RGB display. This type of display can be found at sports arenas, the NASDAQ building in New York, and billboards in Las Vegas.



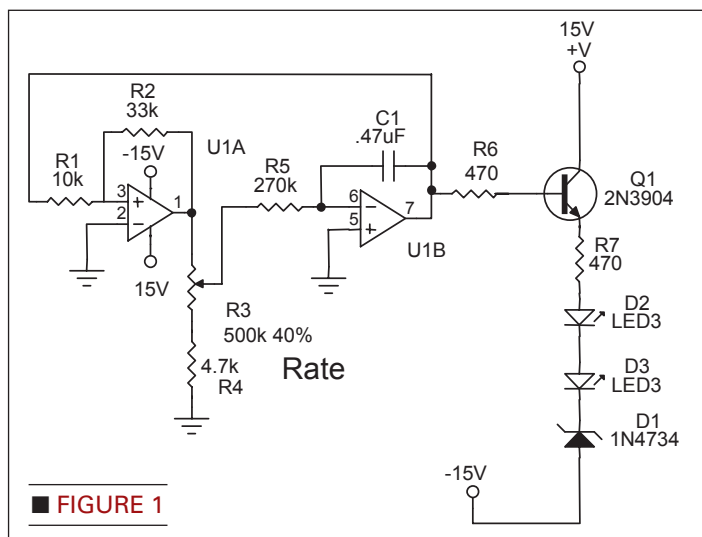
Seeing these displays gave me a couple of ideas. While a full-on LED “video display” was out of the question for a DIY project, I wondered about combining the light from a red, green, and blue LED into backlighting for a display or illuminating a Plexiglass sign. Even though PIC controllers and BASIC Stamps are the staple of DIY these days, I started thinking analog. I figured if I drove each LED with the output of a Low Frequency Oscillator (LFO),

as each color LED faded in and out, the color of the display light would randomly change. In theory, it would change throughout the entire visible spectrum. Then I started thinking about what would look good backlit. I had some 3/4” thick Plexiglass left over from an earlier project and I had a nephew’s birthday coming up. Hmmm. This sounded like the start of a project to me!

Some initial experimentation showed me that the light from the separate LEDs wouldn’t perfectly combine, but the effect was rather unique and interesting by itself. The first RGB LED I came across worked the same way. It had two blue LED chips in it along with one red and one green. Powering them all up with recommended currents for “white” looked good, but you could still make out each color separately. It looked like when you step in close to a TV set; you can make out each individual pixel. Interestingly, white LEDs are actually high intensity blue or UV LEDs that have a phosphor coating on the die that absorbs the light and phosphoresces white. Both the technique and the light spectrum are similar to fluorescent light bulbs; the difference being how the phosphor is excited.

There are two parts to the project presented here: the electronics portion and then the actual Plexiglass work. Starting with the electronics, check out the schematic in Figure 1 and follow along.

The LFO circuit is built around two sections of an



operational amplifier. The stage formed around U1A, the 10K and 33K resistors form a Schmitt trigger. The resistor ratio causes it to change state up to 2/3 of the supply voltage or ± 10 Vdc. The output of the Schmitt trigger feeds the second op-amp stage U1B, which is an integrator. The output of the integrator is fed back to the input of the Schmitt trigger.

Here is how the oscillator works. Assume that the output of the Schmitt trigger is low (at the negative supply rail). U1B has a negative voltage applied to its inverting input. The actual value is determined by the setting of the 500K potentiometer. This causes the output of U1B to swing positive in an attempt to bring the inverting input pin to the same voltage as the non-inverting input, which is at ground potential. This voltage starts charging the .47 μ F capacitor and at the same time applies the increasingly positive voltage to the input of the Schmitt trigger. When the voltage reaches approximately 10 volts, the Schmitt trigger will change its output to the positive supply rail. Now a positive voltage is applied to the input of the integrator and U1B tries once again to bring both of its inputs into agreement and starts discharging the .47 μ F capacitor. In reality, it is actually charging it in the opposite direction.

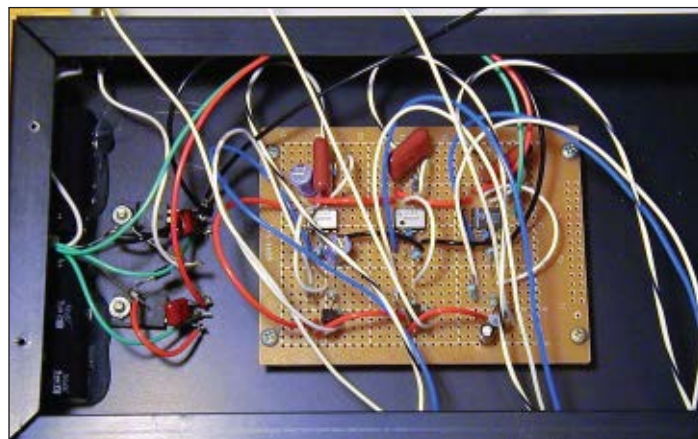
First, it discharges it, and then charges it negatively. Once the voltage on the capacitor reaches approximately -10 volts, the Schmitt trigger changes state once again and the cycle repeats itself. With the component values selected, the LFO will oscillate from several times a second to about one cycle in 30 seconds as determined by the setting of the 500K potentiometer. I find that slower settings for the color changes work better but it is fun to speed things up, too.

The rest of the circuit is basically an emitter follower formed by Q1, which provides enough current to drive the LEDs and buffer the output of the op-amp. The 470 ohm resistor on the base of Q1 minimizes loading on the integrator and protects Q1. The 470 ohm resistor in series with the LEDs provides current limiting to the LEDs. The zener diode determines the voltage that the LEDs begin to light up at. This is a key to the functioning of the circuit. Initially, I drove the LEDs with the output of the LFO and the brightness varied with the output voltage as expected. It looked nice but something wasn't right, I never had any color fully off allowing the other two to blend. Nor did I ever have only one of the colors by itself. What was needed was off time for each LED. That is what the zener provides by determining the voltage in the LFO's cycle that the LEDs turn on.

Let's look at the actual voltages seen by the LEDs: Because we are running from the -15 volt rail to a maximum positive 10 volts, there is a 25 volt range the LEDs are exposed to. The zener diode combined with the forward voltage drop in the LEDs themselves narrows the voltage range by 10 to 12 volts, depending on the color (more on this later). What I learned from initial experimentation is that along with fading in and out, you need dark time for each color.

Once the negative swing drops

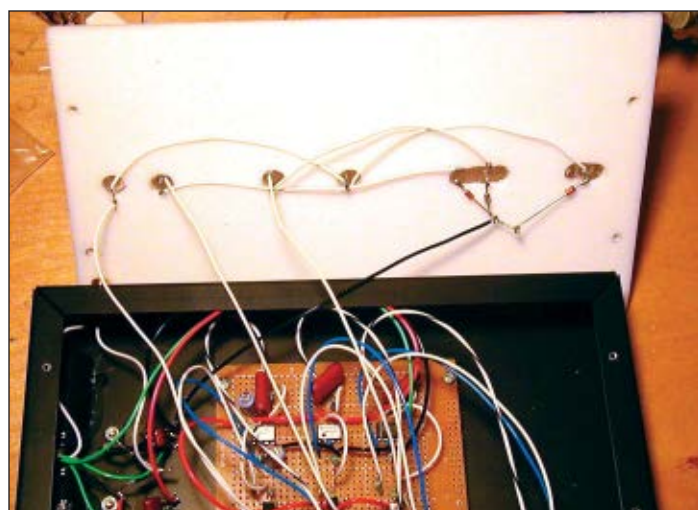
■ Illuminame circuit board.

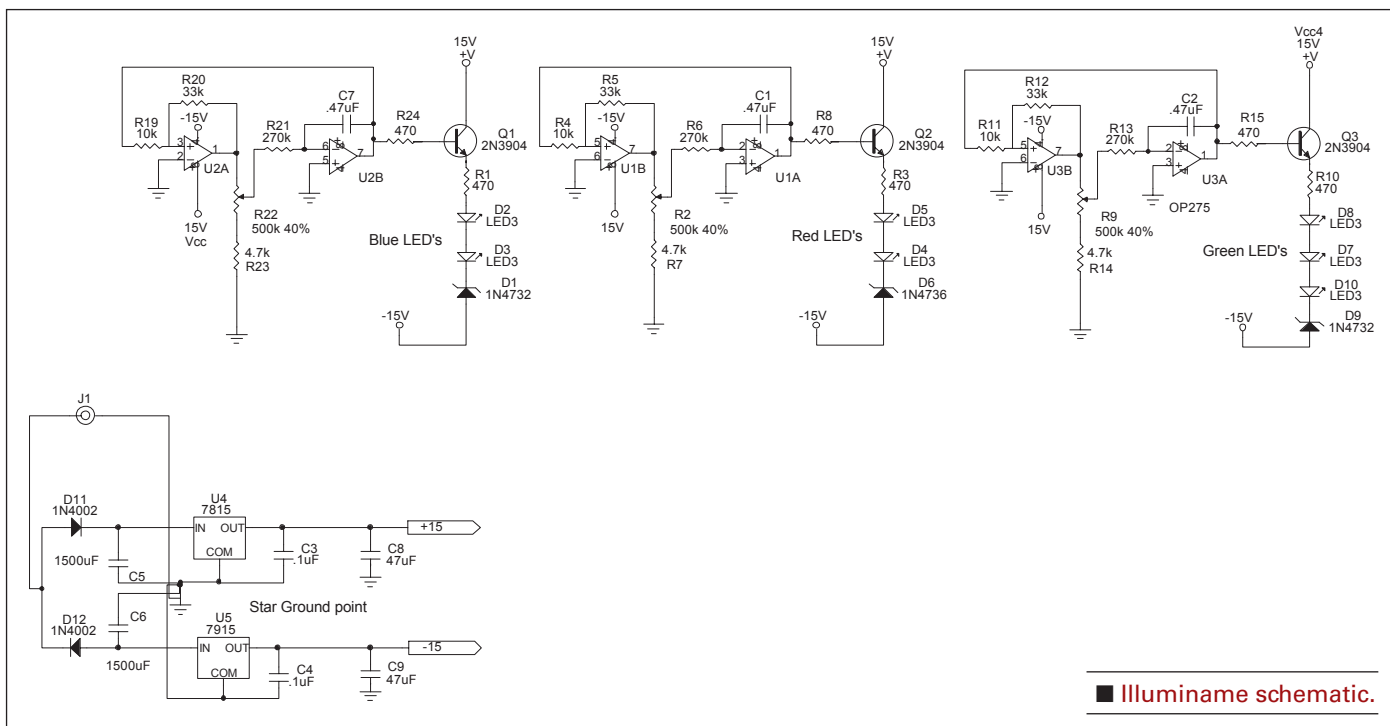


below -3 to -5 volts, the LEDs remain completely off until the voltage returns on its upswing. If you have looked ahead to the complete schematic, you will notice I am using two blue, two red, and three green LEDs. The reason for the extra green is that the green LEDs I am using are not as bright as the blue and red. They are "pure green," meaning the wavelength of light they put out is closer to the pure green of the visible spectrum. Most green LEDs tend to be a little on the yellow side. The downfall of this is that they are not as efficient as other ultra bright LEDs. To compensate for this, I use an extra one.

Okay, here is the math and physics behind the different zener diodes used. Each LED, based on the wavelength of light it produces, drops a different voltage. Blue is the shortest wavelength, highest band-gap energy, thus highest voltage drop. The blue LED drops about 3.6 VDC, the pure green about 2.2 VDC, and red is about 1.7 VDC. So the blue LEDs all by themselves drop 7.2 volts; adding in the 4.7 volt zener, we have 11.9 volts total. The red LEDs drop a combined 3.4 and with a 6.8 volt zener combine to 10.2 volts total. The pure greens combined drop 6.6 volts which, with a 4.7 volt zener, combine to drop 11.3 volts. So, now we have narrowed the voltage range to the LEDs to about 15 volts. With a 470 ohm current limiting resistor, they see a maximum current of

■ Illuminame LED wiring with zeners.





about 32 mA. In a dark room, they are very bright.

Ultra bright LEDs are available from several sources and the list is growing rapidly. My favorite source is **www.superbrightleds.com**. I have purchased both individual LEDs and LED products from them. For this project, I recommend RL5-B5515 for blue, RL5-G5023 for green, and RL5-R5015 for red. There is continual improvement in LED technology and my favorite website for the latest info is **www.misty.com/people/don/led.html**. It is maintained by Don Klipstein and has links to every major source and manufacturer of LEDs.

Electronic Construction

I built four of these on my favorite prototyping board — the RadioShack #275-168. This lets you solder in DIP ICs and then make connections to the pins. I put all three _____ op-amps in one row and then the three

■ **FIGURE 2**



transistors on another row above the ICs. This seemed the most logical layout. I mounted the circuit board roughly in the middle of a 9x5x2 enclosure with enough room to mount the two voltage regulators near by. I am using NJR7815's and NJR7915's from Japan Radio. Electrically, they are the same as other 7815/7915s but they are in a completely insulated T-220 case. This simplifies construction because you can mount them right to the case without any insulation or special hardware. I hot glued the two 1,200 μ F filter capacitors to the case near the regulators and am "floating" the two diodes off of the capacitors. The rest of the power supply circuitry is point-to-point wired. I find it useful to wire and test the power supply portion prior to connecting the supply to the rest of the circuit.

The three 500K potentiometers are mounted to the front panel. If you are wondering about how a 12 VAC transformer can supply 15 volt regulators, there are two factors at work. First is that the 12 VAC is an RMS value. After being rectified, the peak is 1.41 (square root of 2) times the RMS value. This causes the filter capacitors to charge to just under 17 volts. The actual voltage is about 18 to sometimes as high as 20. This is due to the fact the transformer is rated to provide 12 VAC at full current draw. If you are using less current, the output voltage will be higher.

Making a Name for Yourself

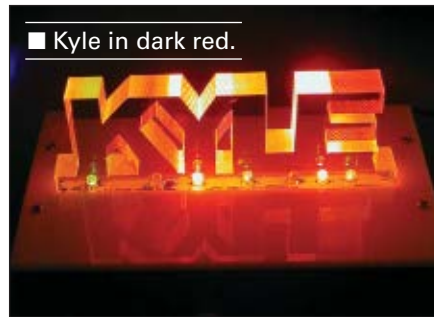
Okay, now the difficult portion of construction, the name itself. As I mentioned earlier, I already had some 3/4" Plexiglas from a previous project, but I wanted to make sure that it was available to the average

■ **FIGURE 3**

experimenter so I checked with a local plastic store in my area; check the Yellow



■ Kyle.



■ Kyle in dark red.



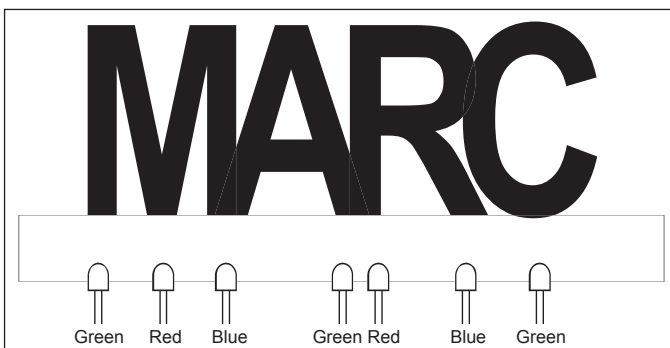
■ Kyle lit up.

Pages for your area. This revealed that I could get up to a one inch thick plexiglass cut to order for a modest price. Plexiglas is sold by the square foot, so you can buy a four or six inch wide piece and get enough for several projects by purchasing one square foot (or for a practice round of sawing). The best way to layout the design is to print out the name and then glue the printout onto the Plexiglass protective covering. After cutting, it will peel off with the covering.

I “joined” the letters by adjusting the space between characters in Word. Any desktop publishing program and most Word processors allow you to do this. I made my letters 200 to 300 points tall, which is two to three inches tall. To condense the spacing between letters in word, go to the format menu and select font and character spacing; the amount depends on both the size of your letters and the look you wish to achieve (see Figure 2). I found Arial Bold works best. After you print the name, use a ruler and draw a line along the bottom and 1-1/2 inches or so below the name to provide the material that will be drilled into for the LEDs. The final result will look like Figure 3.

Now, the fun part comes in — cutting out the name. A bandsaw and a scroll saw are really required for a successful project. A friend with these tools really helps. The Plexiglas isn’t hard to cut but unlike wood, it tends to melt and I recommend practicing on a couple scrap pieces before tackling the name. One of the interesting things I learned is that the rough edges from the saw cuts look much better than if you sand them down and polish the edges. The rough edges give the light something to “light-up.” I polished my first attempt at a name and the light just passed through, not stopping to light anything up. Then, I roughed the edges of the letters up and achieved a

■ FIGURE 4

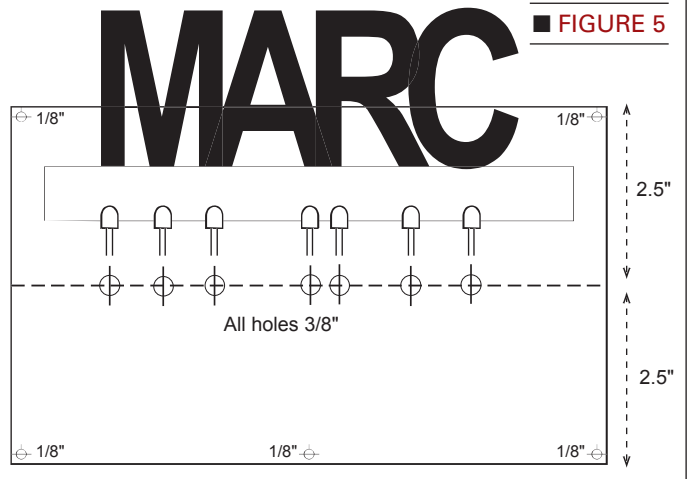


■ Jenna lit up.

base out of clear or translucent 1/4” thick Plexiglass.

Once you have the name cut out, the bottom needs to be polished for light reflection. This is also the surface that the LEDs are mounted in. The best way that I found is to use a flat surface (a scrap piece of Plexiglas works great) and lay a piece of medium grit sandpaper on it. After the surface is even, using 320 grit, and finally 600 grit wet sand until there are no scratch marks. Final polishing is completed with either plastic polish or Brasso®. Brasso contains a fine abrasive that works great on plastic. After the bottom edge is polished, you need to drill the holes for mounting the LEDs. A drill press really makes life simple here. The LEDs are about .200” in diameter. I used a .203” drill bit, which left just enough room for epoxy to mount them with. I centered the LEDs below the solid parts of the letters. This allowed maximum light transfer (see Figure 4).

■ FIGURE 5



PARTS LIST

ITEM	QTY	DESCRIPTION
<input type="checkbox"/> C1,C2,C7	3	.47 μ F
<input type="checkbox"/> C3,C4	2	.1 μ F
<input type="checkbox"/> C5,C6	2	1,500 μ F
<input type="checkbox"/> C8,C9	2	47 μ F
<input type="checkbox"/> D1,D9	2	1N4732
<input type="checkbox"/> LED3	7	See text
<input type="checkbox"/> D6	1	1N4736
<input type="checkbox"/> D11,D12	2	1N4002
<input type="checkbox"/> J1	1	
<input type="checkbox"/> Q1-Q3	3	2N3904
<input type="checkbox"/> R1,R3,R8,R10,R15,R24	6	470
<input type="checkbox"/> R2,R9,R22	3	500K var
<input type="checkbox"/> R4,R11,R19	3	10K
<input type="checkbox"/> R5,R12,R20	3	33K
<input type="checkbox"/> R6,R13,R21	3	270K
<input type="checkbox"/> R7,R14,R23	3	4.7K
<input type="checkbox"/> U1-U3	3	OP275, NE5532 or similar
<input type="checkbox"/> U4	1	NJM7815
<input type="checkbox"/> U5	1	NJM7915
<input type="checkbox"/> Aluminum case 2x5x9 "bud" or equivalent	1	
<input type="checkbox"/> Wall wart 12 VAC transformer	1	



Once you have drilled the holes, the LEDs get glued in with clear epoxy. Optically clear epoxy is available but is very expensive. The clear stuff from Home Depot works just fine. To make wiring easier, position the LEDs so that the anode leads (the longer ones) are all facing the same direction. The next step is to prepare the base that the name is mounted on. Draw a line down the center of the top piece and then mark off holes for the LED leads to come through as shown in Figure 5.

After marking the base, drill 3/8" holes in the Plexiglas for the LED leads to stick through. Don't forget the small holes for the mounting screws! Remove the paper covering from the base Plexiglas and check that the name piece fits flat on the base. I had to do a little adjustment by enlarging a few of the holes. After the fit has been verified, glue the name to the top with plastic glue. Let the pieces set up over night.

Writing Time

Now, it is time for the final wiring. The LEDs require some point-to-point wiring. Each color gets wired together in series. A nine-volt battery with a 330 ohm resistor in series with it makes a great "idiot check" tool to ensure you have the right color and polarity. Once you have a series "string" of LEDs for each color, wire its associated zener diode to the cathode (negative) side and then to the negative 15 volt supply rail. Then, wire the circuit board outputs to the anode side of the LEDs. Once you think everything is wired correctly, take a five minute break and then re-check all your wiring again. Believe me, it takes less time to check your work than it does to replace components. I still find myself verifying this rule once in a while. If everything looks good, it is time for the smoke test. Apply power and you should see all the lights come on and oscillate. Adjust the front panel controls and make sure that each color changes its rate of oscillation. A common mistake is to reverse the outer potentiometer leads and have the controls work backwards. Once all the electronics have been verified, it is time for final assembly.

Carefully screw the top to the base. I put little felt discs on the bottom of the case so as to not scratch a surface the Illuminame is set on. This backlighting technique can be used for more than just a cutout name. Try embedding the LEDs in a casting resin for yet another unique visual sculpture. Good luck and happy building! **NV**



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REMOTELY PROGRAMMABLE POWER

BY PAUL LAPSANSKY



The recent demise of my bench power supply — a project I built it back in 1987 — convinced me that it was now time to build a new one. The basic design of my original power supply was relatively straightforward; 1.5-15 volts DC, LM317 voltage regulator,

adjustable via a potentiometer, and an analog panel meter to display voltage out. My basic power needs have changed very little since then.

When I first thought about this project, I simply wanted to see if I could do it. I had never worked with FFTs before or developed an interface and software for a graphics LCD. It was a very interesting and rewarding experience! One of my primary uses for this device will be to monitor the output of a Public Address (PA) system I am responsible for. It lets me see if any frequencies are being emphasized too much or not enough. I can also see the frequency of any feedback and then adjust the equalizer accordingly. Used in conjunction with my DDS (N&V, November '06), it can be used to determine the acoustic characteristics of a room or PA/recording system.

Most of my projects are PIC based or other breadboard projects requiring less than an amp of current. A couple new features I did desire were presets for the most common voltages and a digital display with current monitoring, as well as voltage output. My bench space was limited along with my budget, but I did have an old Windows 98 PC on my bench with an available serial port. I decided to replace as much as I could of the functionality normally found with an adjustable power supply — i.e., potentiometers, LCD panels, etc., with virtual equivalent components. Aircraft manufacturers such as Boeing and Airbus have been doing this for quite a while now and often refer to it as the “virtual flight deck.” This design concept not only makes the power supply easier and cheaper to build, but also allows for quick updates and customization for little or no additional expense since only the software needs to be changed.

My new programmable power supply or “PPS” for short is operated via a PC and the PPS software. Any

computer with an RS-232 serial port and terminal emulation software can be used to control the PPS, but the PPS software is a Win32 application and requires Windows 95 or higher. The fact that the PPS will work with older hardware and versions of Windows is great if you have an extra PC lying around. If you have the occasional need for a power supply in the field, this PPS is the ideal solution as well, since it can operate stand-alone without a PC. Once set to any value between .8 and 15 volts, the PPS will retain that setting even when powered off.

Theory

Our PPS's ability to operate stand-alone without a PC is accomplished by utilizing a Maxim DS1804 nonvolatile 100-position digital potentiometer to adjust the output voltage. Once set, the DS1804 has a built-in EEPROM that automatically retains its setting even when powered off. The regulator is the heart of any linear power supply. I originally intended to use an LM317 for regulation just like in my original power supply but quickly discovered a problem. Two resistors are required by the LM317 — one fixed and one variable — in-order to vary the output voltage. These two resistors create a voltage divider with the greater of the voltage drop across the variable resistor. This is normally not a problem except we are replacing the variable resistor with the DS1804 and the maximum voltage across the DS1804 terminal pins can't exceed the supply voltage or 5.5 volts. Since the desired maximum output voltage is 15 volts, this would destroy the DS1804 once the output voltage exceeded 5.5 volts. After some

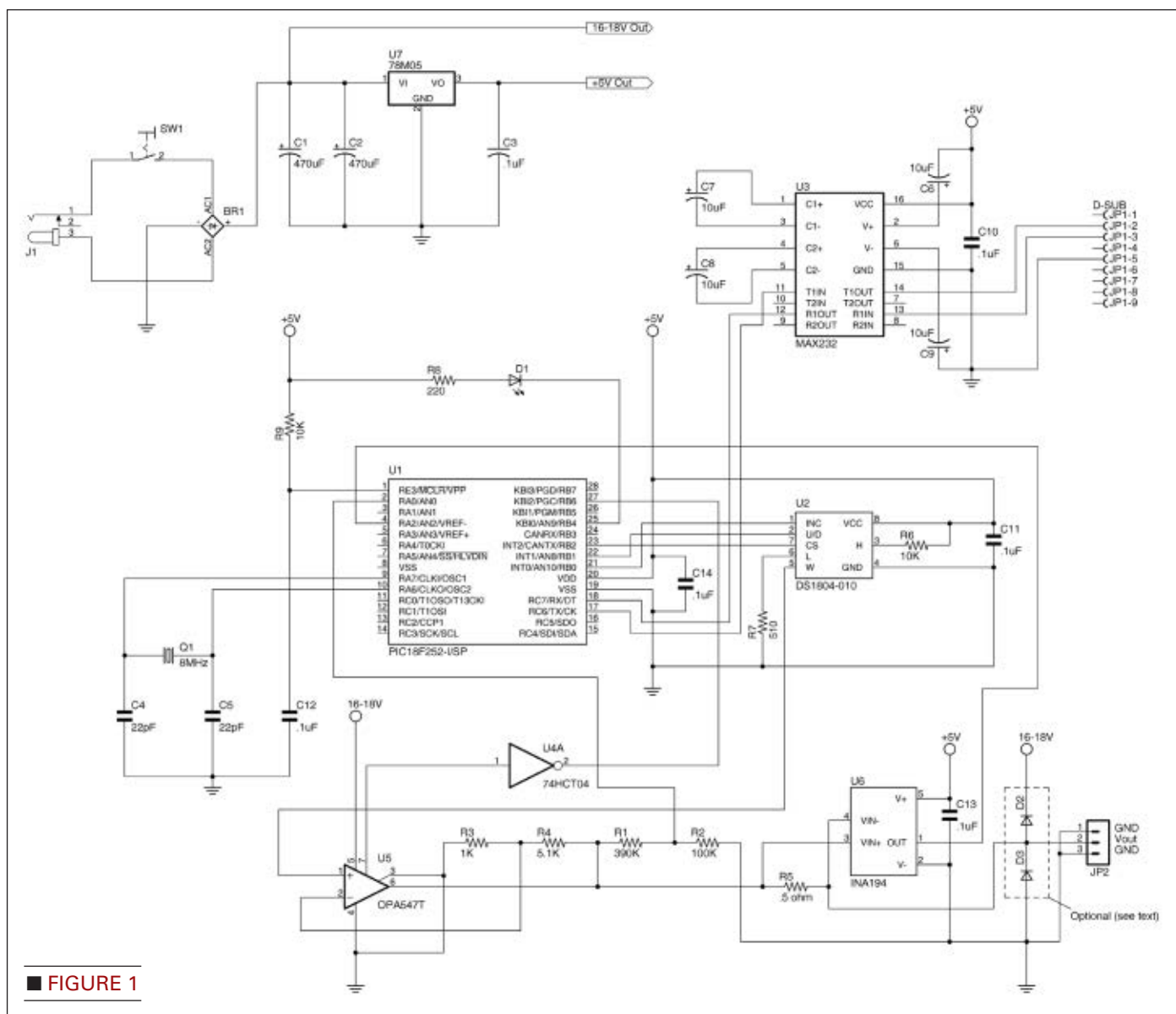


FIGURE 1

searching on the Internet, I found an ideal solution not in a regulator but an op-amp: the Burr-Brown (now Texas Instruments) OPA547 high-voltage/high-current operational amplifier. The OPA547 is ideal for this project. It has a wide output voltage swing, high current output (500 mA continuous, 750 mA peak), is internally protected against over-temperature and current overloads, and can be monitored to determine if it is in thermal shutdown. The OPA547 is capable of providing user-selected current limit via pin 3 but this has been tied to ground to provide maximum current output. Thermal shutdown status is provided via pin 7 of the OPA547. A Burr-Brown INA194 current shunt monitor is used to monitor current output. The INA194 senses voltage drop across a .2 ohm shunt resistor and outputs the measured current as a voltage that is fed to the A/D converter of a PIC18F252 microcontroller. If the OPA547 is the heart, then the PIC18F252 is the brain of the PPS and receives status

input from the OPA547 and INA194, as well as controls the DS1804 and communicates with the PC via a MAX232 RS-232 driver/receiver. Output voltage is also monitored by the PIC's A/D converter via a voltage divider across resistors R1 and R2. LED D1 provides status of the OPA547 while U7, a 78M05 voltage regulator, provides the regulated 5V required by the system. Diodes D2 and D3 are optional and recommended if the PPS will be driving motors or other EMF-generating loads.

Finally, in order to reduce the size, cost, and complexity of the project I decided to use an external AC adapter instead of an internal transformer to supply the 18-20V @1A needed to regulate down to the desired output voltage. Any adapter meeting these specs should suffice. You can purchase an inexpensive adapter from most electronics suppliers. Jameco Electronics (www.jameco.com) has a good selection and is reasonably priced. Or, you can do like I did and salvage one from an old piece



■ FIGURE 2. Front view of completed PPS.



■ FIGURE 3. Inside view of completed PPS.

of equipment. I got mine from a surplus HP DeskJet 720C inkjet printer. They are inexpensive and readily available from places like eBay. Because of the use of bridge rectifier BR1, this power adapter can be either an AC or DC power source. Capacitors C1 and C2 help smooth out this power (Figure 1).

Construction

I have tried my best to avoid using surface-mount components in order to make this PPS as simple and as easy as possible to build. Unfortunately, U6, the INA194, is only available in a surface-mount package and so can be a bit tricky to solder. Because of this, I recommend using a printed circuit board (PCB) and soldering in U6 first before everything else. I have made a silk-screened PCB, as well as a pre-programmed 18F252 microcontroller available for purchase from my website (www.rad220.com). If you choose to program the 18F252 yourself, you can download the PPS firmware along with the PPS.EXE Windows application from either my site or the *Nuts & Volts* website (www.nutsvolts.com). If you don't require current monitoring, then you can eliminate U6. If you choose to do this, then you can also eliminate capacitor C13 and shunt resistor R5. Just remember to replace R5 with a jumper wire.

After soldering in U6, component placement order is not critical. I do recommend using sockets for all the remaining ICs, especially U1 and U2. It's probably easiest to first start with the smallest components and leave the larger ones such as capacitors C1 and C2 and bridge rectifier BR1 for last. One critical step that needs to be done before installing resistors R1, R2, and R5 is to measure their resistance with a good quality DMM as these values will be needed later by the software to calibrate the PPS's voltage and current monitoring.

A heatsink is required for op-amp U5 and regulator

U7 in order to insure that the PPS does not overheat when driving higher current loads. You can either purchase a readymade heatsink or make your own. I made mine from a strip of anodized aluminum I purchased at my local hardware store (Figure 3). Whether you purchase or make one, make sure it is large enough to dissipate the heat from both U5 and U7. Finally, I strongly recommend enclosing PPS in some type of cabinet. You can choose to make one or purchase a ready-made one (Figure 2). Either way, make sure it has adequate ventilation. If not, you can always add additional ventilation by drilling extra holes (especially around the heatsink) to dissipate the heat.

After all components have been installed, it is time to power up and test our PPS. First, you will need to plug in the power adapter and then power on the PPS. After about a two to three second delay, the LED should come on. The delay is there to provide an opportunity to update the PPS's firmware should the need arise. When powered up, a boot loader is first executed. The boot loader waits for a command from the PC instructing it to update the firmware. This allows the firmware to be updated in-circuit via the serial port. If the PPS does not receive the command within about three seconds, it then begins executing the main program and the LED should come on. If the LED does not come



■ FIGURE 4. Screenshot of PPS program.

on, disconnect power to the PPS and check to make sure that there are no open solder connections and all component orientations — especially LED D1 — are correct. Reconnect power to the PPS and check to make sure there is five volts at pin 20 of U1. Also, make sure pin 1 of U1 (MCLR) is high and the case of crystal Q1 is not shorted to any traces on the PCB. If you get a blinking LED, make sure U4 uses HCT logic and not another type.

Configure and Calibrate

If all goes well and you've got your PPS working, then you are ready to connect to your PC. You will need to connect a standard RS-232 serial cable from the PPS to your computer. Next, copy the PPS.EXE program to a folder on your hard drive. You may want to create a

shortcut to it from the desktop, as well. Execute the PPS.EXE program. It will create a file called PPS.DAT in the folder that you copied PPS.EXE into. This file contains the default settings for the PPS software. You should see a green LED in the PPS program under the LCD panel (Figure 4). If you get a "PPS Device Not Found!" message, then you need to check and make sure that the program is set to the correct COM port under the "Options" menu. If it isn't, set it to the correct port (PPS only supports COM1 and COM2) and restart the program. If you get a "COM ERROR!" message, then either the COM port you have selected is unavailable or is in use by another program. If you still are not able to connect to your PC, then you will need to do some additional troubleshooting. Close PPS.EXE and run Hyper Terminal or another terminal emulation program of your choice. Select the appropriate

COM port and set the program to 9600 baud, eight data bits, no parity, one stop bit, and "Flow Control" to none. Power the PPS off and back on. You should see a couple lines of the letter "g" followed by a "PPS READY" message. If you fail to get this message, then the problem most likely is either the PPS unit itself or the cable. Follow the troubleshooting tips from above or try another cable.

Once you have the PPS communicating with the program, it is time to calibrate. Select "Calibrate" under the "Options" menu. Here, enter the values that you measured with a DMM for resistors R1, R2, and R5. Doing this will insure better accuracy for voltage and current monitoring. If you elected to not install the INA194, then you can just leave R5 to the default value and uncheck "Current Monitoring" in the "Options" menu. "G1" is the gain value for the INA194 and can normally be left to the default value. If you find that the current monitoring is slightly off, you can tweak this value

PARTS LIST

ITEM	DESCRIPTION	NOTES
Resistors		
<input type="checkbox"/> R1	390K	1/4W 2%
<input type="checkbox"/> R2	100K	1/4W 2%
<input type="checkbox"/> R3	1K	1/4W 2%
<input type="checkbox"/> R4	5.1K	1/4W 2%
<input type="checkbox"/> R5	0.2 Ω	1/2W 2%
<input type="checkbox"/> R6,R9	10K	1/4W 5%
<input type="checkbox"/> R7	510 Ω	1/4W 2%
<input type="checkbox"/> R8	220 Ω	1/4W 5%
Capacitors		
<input type="checkbox"/> C1,C2	470 μ F electrolytic	35V or higher
<input type="checkbox"/> C3,C10-C14	.1 μ F	
<input type="checkbox"/> C4,C5	22 pF	
<input type="checkbox"/> C6-C9	10 μ F electrolytic	16V or higher
Semiconductors		
<input type="checkbox"/> U1	PIC18F252-I/SP microcontroller	Part No. PIC18F252-1/SP-ND
<input type="checkbox"/> U2	DS1804-010 NV trimmer pot	Part No. DS1804-010+-ND
<input type="checkbox"/> U3	MAX232 RS-232 driver/receiver	Part No. 296-1402-5-ND
<input type="checkbox"/> U4	74HCT04 hex inverter	Part No. 296-2083-5-ND
<input type="checkbox"/> U5	OPA547T power op-amp	Part No. OPA547T-ND
<input type="checkbox"/> U6	INA194 current shunt monitor	Part No. 296-17164-1-ND
<input type="checkbox"/> U7	78M05 positive voltage regulator	Part No. 296-11134-5-ND
<input type="checkbox"/> BR1	KBU4D 4A bridge rectifier	RadioShack Part No. 276-1181
<input type="checkbox"/> D1	LED	
<input type="checkbox"/> *D2,D3	11DQ03 Schottky diode	Part No. 11DQ03-ND
Miscellaneous		
<input type="checkbox"/> Q1	8 MHz crystal	Part No. X417-ND
<input type="checkbox"/> J1	Power jack 2.1 mm PCB	Part No. CP-102A-ND
<input type="checkbox"/> JP1	Nine-pin D-sub female PCB	Part No. 609-1487-ND
<input type="checkbox"/> SW1	SPST switch	
<input type="checkbox"/> Case, binding posts, PCB, heatsink, AC adapter		

*Optional (see text)

NOTE: All part numbers are from Digi-Key unless stated otherwise.

for better accuracy. After you have entered all the values, click on "OK" to save them to the PPS.DAT file. Calibration of the PPS is now complete.

Using

Using this PPS is very straightforward. The LCD displays the voltage and current output. You can change the voltage by either moving the slider or using one of the preset voltages. If you get a red LED, then the PPS is in thermal shutdown. It will also display "Thermal Shutdown" on the LCD. If this occurs, power off this PPS and allow it to cool down. Disconnect the load and determine what its current demands are. Remember, the PPS is designed to provide up to 500 mA of current (750 mA non-continuous), but this depends on other factors including the type and size of heatsink, as well as case size and ventilation. If you get frequent thermal shutdowns, you may want to consider using a larger heatsink or adding additional ventilation.

Final Comments

That's all there is to it. Remember, that once the desired output voltage has been set, this PPS can be used with or without a PC. If you would like to create your own software for your PPS — perhaps for Linux or another operating system — I've included a list of the commands the PPS uses to communicate with the PC (Table 1). **NV**

SOURCES

- For components and hardware: www.digikey.com; www.jameco.com; and www.radioshack.com.
- For information on the Microchip PIC18F252: www.microchip.com.
- For information on the OPA547T and INA194: www.ti.com.
- For information on the DS1804: www.maxim-ic.com.
- To purchase a programmed PIC18F252 or silk-screened PCB or for more information visit: www.rad220.com.

TABLE 1

Command	Function
V	Retrieve Vout (raw 10-bit output)
I	Retrieve Iout (raw 10-bit output)
U	Increment voltage control POT
D	Decrement voltage control POT
S	Request status ("PPS READY" or "SHUTDOWN")
R	Reset
F	Firmware Revision

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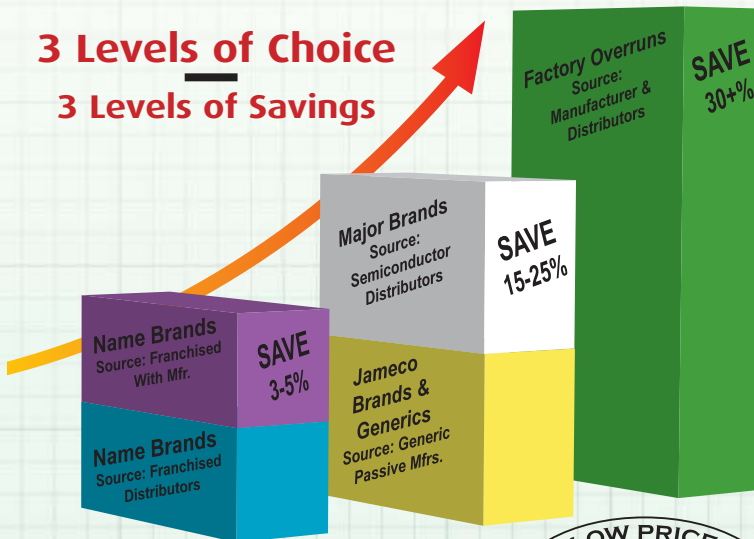
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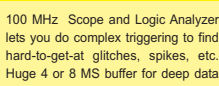
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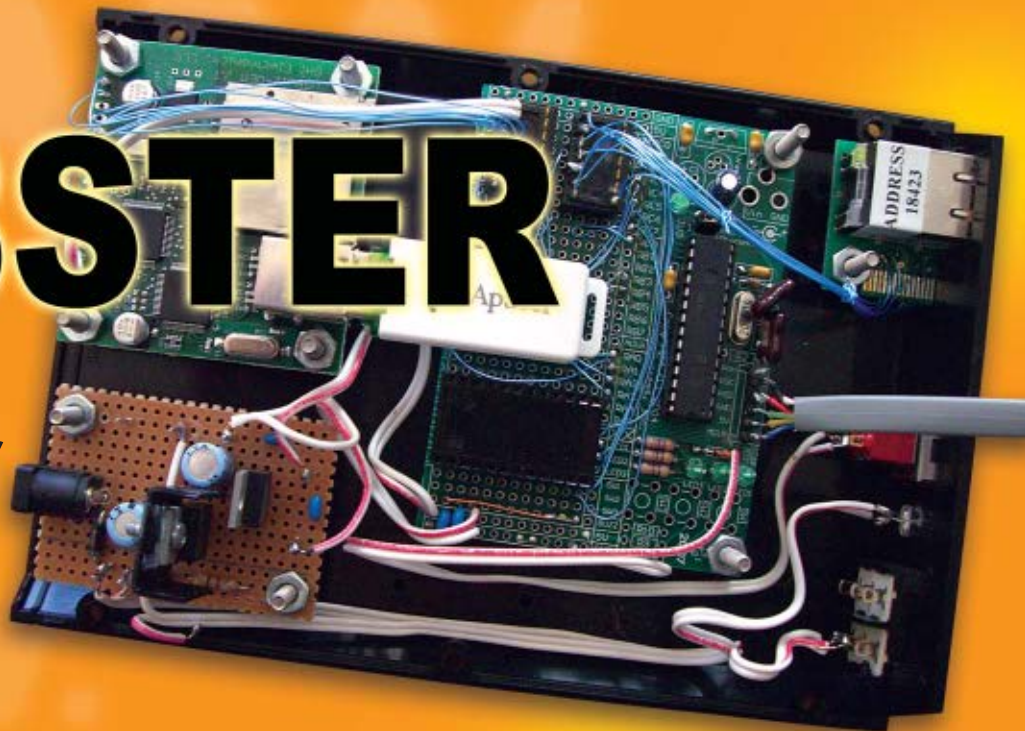
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WEBSTER

The Mini Web Server

by Craig A. Lindley



I'm one of those people who walk around the house after dark and turn off all the lights that have been left on. I do this because I was trained by my parents to conserve electricity. This was important then and is even more important now as we all try to cut back on our energy use and carbon footprint. In thinking about conservation, it occurred to me that hosting my personal website on a desktop PC used a lot of energy. Even without a monitor, a desktop PC draws about 120W of power or about 200 KWH a year. So, I designed and built a low power alternative – Webster, the mini web server. There are many uses for Webster-like web servers including:

- 1) As a personal web server for sites that don't use a lot of rich media.
- 2) To provide a web presence for a business for publishing hours, directions, etc.

- 3) As a toy for children who want to have their own website.

Webster's features include:

- 1) Low power operation. Only 160 mA is required in the idle state and 300 mA when actively serving pages. At nine volts, this works out to about 2.7 watts.
- 2) Small size. The prototype (see Photo 1) is about the size of a hardbound book.
- 3) Built using the highly integrated PIC18LF2620 microcontroller (μ C).
- 4) Features 10Base-T Ethernet connectivity.
- 5) Support for static and dynamic (DHCP) IP address assignment.
- 6) TCP/IP support using version 4.16 of the Microchip TCP/IP stack optimized for serving static HTML pages.
- 7) Support for basic authentication for website access control.
- 8) USB host interface with FAT file system allows web page storage on pluggable USB Flash drives or SD media.
- 9) Easy to build. Webster is mostly made up of assembled and tested modules.

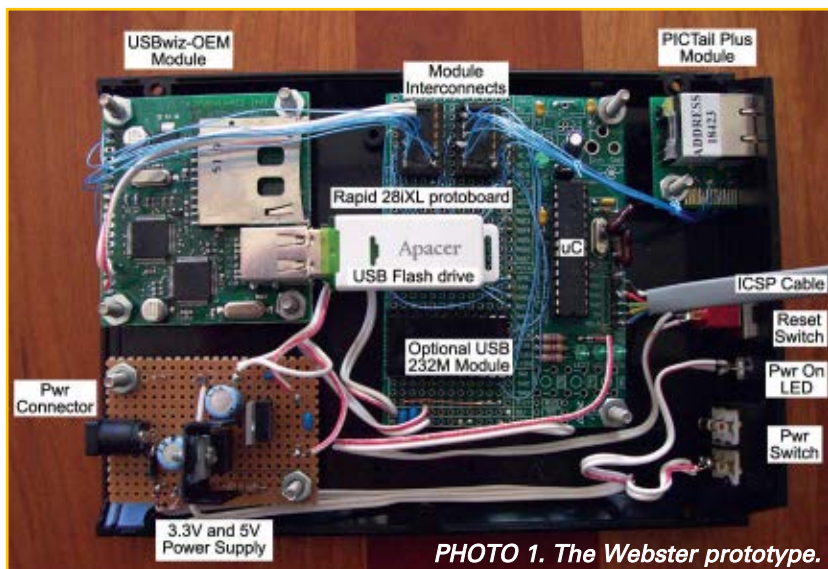


PHOTO 1. The Webster prototype.

Webster and Me

I use Webster for my personal website for numerous reasons. Besides the power issue, Webster can be put on the Internet without concern for viruses and spyware. Webster's software is written entirely in C with no underlying operating system with exploitable security flaws. Since — by design — there isn't any write access to the underlying FAT file system, it is not possible for the website content to be compromised. In addition, since no sensitive data is kept on the Flash file

system, there is nothing for a hacker to find. Finally, since Webster supports basic authentication, access to the website can be controlled with a user name and password. Of course, like any web server, Webster could be brought to its knees (and its legs are really short) by a denial of service attack. Building and maintaining a website with Webster is easy. Web pages are composed on a PC using any HTML editor (I use Composer by Mozilla) and when the design is finished, the files are copied onto a USB Flash drive which is subsequently plugged into Webster. When Webster's reset button is pressed, the new or modified website becomes operational. It is just that easy.

It is important to note at the most basic level any web server is just a device that understands and implements the HTTP protocol; a web server doesn't influence website content. A web server's job is to stream requested content to a user's browser whether that be HTML files, image files, PDF files, MP3 files, etc. This is important because it is the content of the served up files that may or may not be compatible with different browsers. If the website you serve with Webster works with Internet Explorer but not with Firefox, it is probably not Webster that is at fault.

Webster Design

As with any new design, I wrote down the requirements I wanted Webster to fulfill and then determined how each could be met. I soon realized each requirement could be met using technology I had seen in *Nuts & Volts Magazine*.

Webster Hardware

As mentioned, the hardware is made up mostly of commercially available modules. I used the USB client port DLP USB232M module for RS-232 like support, the USBwiz-OEM module to provide USB host ports (actually two USB host ports and an SD interface), and FAT file system support and the Microchip PICTail Plus module for Ethernet connectivity. Missing was a power supply and a uC to drive it all.

The DLP USB232M module, the USBwiz-OEM module, the PICTail module, and the three on-board LEDs are all mapped into the uC's I/O space. Signal connections are shown in Table 1. Signals prefixed with WIZ_ are associated with the USBwiz module. Signals prefixed with ETH_ are associated with the PICTail module. Signals with USB_RX and USB_TX are associated with the DLP module. Signals prefixed with LED_ are associated with the three on-board LEDs.

The SPI interface of the PIC18LF2620 uC is used to transfer data serially to and from the USBwiz-OEM and the PICTail modules. Chip select signals, WIZ_CS and ETH_CS, are used to select which module is addressed.

Construction

The Webster prototype was built into a plastic case from an old modem. The case measured 5" wide x 7" deep x 1.5" tall. My first task was to place all of the modules in the case to make sure they fit and to drill holes for the stand-

offs used to mount them. I decided the USB Flash drive would be safer inside the case than out, so the USBwiz-OEM board was positioned appropriately. Construction began once the positioning and mounting was finalized.

I built the power supply module (see schematic) on a small piece of perf board. This circuitry is powered by a nine volt DC 300 mA wall wart. The five volt regulator gets warm to the touch so a heatsink of some kind may be in order. Once completed, I verified a clean source of 5 VDC and 3.3 VDC. An optional power-on LED is shown on the schematic but I believe there are already enough glowing LEDs on the finished server.

As for the μ C and support circuitry, I purchased DHMicro's Rapid28iXL prototype board which is designed for use with 28 pin PIC μ Cs. The basic kit comes with most of the support components needed. I made numerous changes to the prototype board including trimming off the RS-232 portion of the board as I wasn't going to use it (doing this made the board even smaller). I also left all of the power supply components off except for bypass capacitors as I built the power supply separately. I powered the uC board with 3.3V instead of five volts as that eliminated interface components between the μ C and the PICTail board which runs on 3.3 volts.

After assembly of the μ C components, I soldered two 14-pin and one 24-pin wire wrap sockets into the proto area of the Rapid28iXL board. The 14-pin sockets would be used for connecting the PICTail and the USBwiz modules to the μ C. The 24-pin socket is used for the optional DLP

TABLE 1

Signal	Interconnect Connector-Pin	uC Port	Port Pin Direction	uC Pin Number
WIZ_5VOLT	ICT2-1	NA	NA	NA
WIZ_GND	ICT2-2	NA	NA	NA
WIZ_DATARDY	ICT2-3	RA1	In	3
WIZ_BUSY	ICT2-4	RA2	In	4
WIZ_SCLK	ICT2-5	RC3	Out	14
WIZ_DI	ICT2-6	RC5	Out	16
WIZ_DO	ICT2-7	RC4	In	15
WIZ_CS*	ICT2-8	RA0	Out	2
WIZ_RESET*	ICT2-9	RA3	Out	5
ETH_3.3VOLT	ICT1-1	NA	NA	NA
ETH_GND	ICT1-2	NA	NA	NA
ETH_RESET*	ICT1-3	RB4	Out	25
ETH_SCLK	ICT1-4	RC3	Out	14
ETH_DI	ICT1-5	RC5	Out	16
ETH_DO	ICT1-6	RC4	In	15
ETH_CS*	ICT1-7	RB3	Out	24
ETH_INT*	ICT1-8	RB0	In	21
USB_RX	NA	RC6	Out	17
USB_TX	NA	RC7	In	18
LED_0	NA	RC0	Out	11
LED_1	NA	RC1	Out	12
LED_2	NA	RC2	Out	13

NA = Not applicable. Signals marked with * are active low.

USB232M module. As shown on the schematic, the PICTail and the USBwiz modules are wired to the μ C board using 14-pin component headers and the on-board sockets. This was done so these modules could be unplugged while the μ C board was worked on. It's nice to have all of the PIC signals broken out and labeled on the prototype board. It makes wiring easy. I used wire-wrap wire for all of the interconnections.

Once assembly was complete, I connected the μ C board to the power supply and to the ICD2 debugger/programmer. I wrote and downloaded several small C programs to blink the three on-board LEDs just to make certain the μ C was operational.

The PICTail module was wired up next. I couldn't find a mate for the edge connector on the module so I soldered wires directly to the gold fingers. This is delicate work requiring a magnifying glass and steady hands because the fingers are so small and close together. I first soldered wire-wrap wires to the module and then soldered the other end of the wires to a 14-pin DIP component header used for the interconnect. Finally, I soldered wire-wrap wire to the USBwiz-OEM board and terminated the other end of the wires in another 14-pin component header.

With all of the modules wired up, I mounted them in the case. I hard-wired the power supply to the front panel and to the μ C board. After plugging in the wall wart, I again verified the power supply outputs. I checked the voltages after plugging in each module, one at a time.

Once you get this far building your version of Webster, it is time to program the processor with the runtime code. We'll talk about the software next.

Webster Software

All of Webster's software is written in C using the Microchip MCC18 C compiler (student edition) embedded into the MPLAB Integrated Development Environment (IDE), both of which are available free from Microchip. See the Resources sidebar for more information. I used the Microchip ICD2 debugger and programmer (not free) during code development and testing. It interfaces to the Webster hardware via a five wire In Circuit Serial Programming (ICSP) interface. ICD2 interfaces to the PC via a USB interface. ICD2 also has a serial interface, but I never used it.

The Microchip TCPIP stack makes up the bulk of the code, followed by the library of code for the USBwiz-OEM

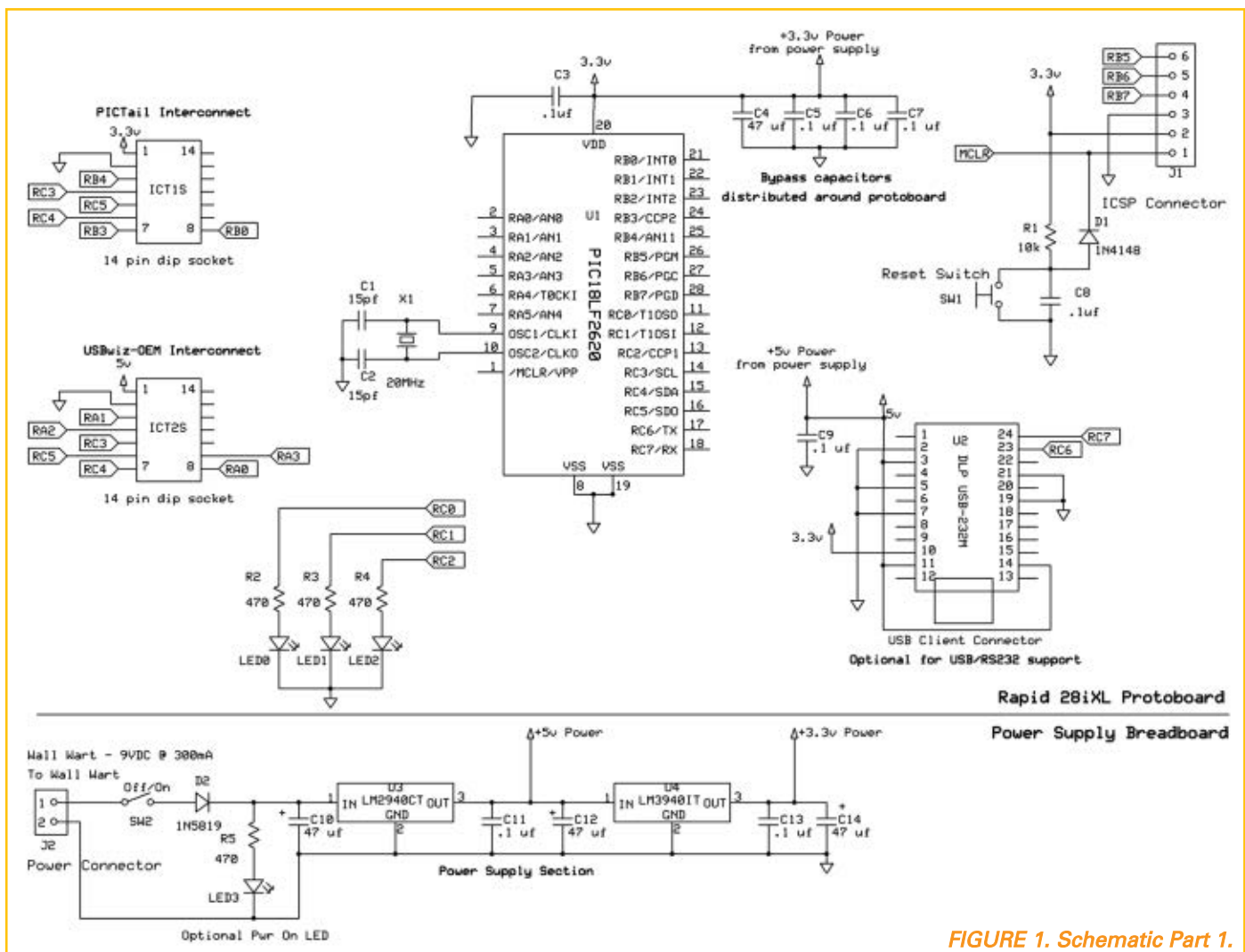


FIGURE 1. Schematic Part 1.

module provided free by GHI Electronics. My software effort consisted of:

- 1) Writing a high level file system interface used to connect the HTTP server code to the file system. (See the files Ffs.h and Ffs.c.)
- 2) Rewriting Microchip's server code (HTTP2.c) to make it as compact as possible as code space was tight. At the same time, I optimized the code for serving static web pages and removed all unneeded functionality.
- 3) Writing the code in main.c which initializes all of the hardware, parses the server's configuration file, and starts the server.
- 4) Tuning the TCP/IP stack to provide 10 TCP sockets and 10 possible simultaneous HTTP connections.
- 5) Generating custom linker command files for optimizing the size of file system buffers, TCP data structures, and Ethernet buffers. One linker command file is required for debugging (18f2620i.lkr) and another for the production code (18f2620.lkr).

All of Webster's source code is available from the *Nuts & Volts* website (www.nutsvolts.com). To utilize this code, you must have the MPLAB IDE and the MCC18 compiler. If you use other code development tools, you will have some work to do. Once you get the code to compile and link, use your programmer to program the uC.

Webster Configuration File

Webster's operation is controlled by a configuration file called "config.dat" that must reside in the root directory

of the Flash drive. The server cannot be configured via RS-232 with the version of the software provided. Webster will blink all three on-board LEDs and halt operation if the configuration file is not found or if an error is detected in the configuration file. A typical configuration file is shown next:

```
//  
// Webserver Configuration File - No blank lines allowed  
//  
Hostname: Webster  
Use DHCP: no  
Use Authentication: yes  
Username: roy  
Password: rogers  
//  
MAC Address: 00-04-A3-00-47-F7  
//  
// IP Addresses - Only necessary if not using DHCP  
//  
Static IP Address: 169.254.1.1  
Static Gateway Address: 169.254.1.1  
Static Subnet Mask: 255.255.0.0  
Static Primary DNS Server Address: 169.254.1.1  
Static Secondary DNS Server Address: 169.254.1.1
```

The configuration file is a human readable text file with each line terminated by carriage return and line feed characters. The code (in main.c) that parses this file is not very forgiving so it is important to not deviate from the format shown. No blank lines are allowed within this file and comment lines begin with "//" starting in the first column. All entries must be in the configuration file even if they are not being used. For example, if DHCP is being used, all of the static entries must still be in the file and must still have a value. The configuration entries can, however, be specified in any order; not just the way shown here. Most entries in the configu-

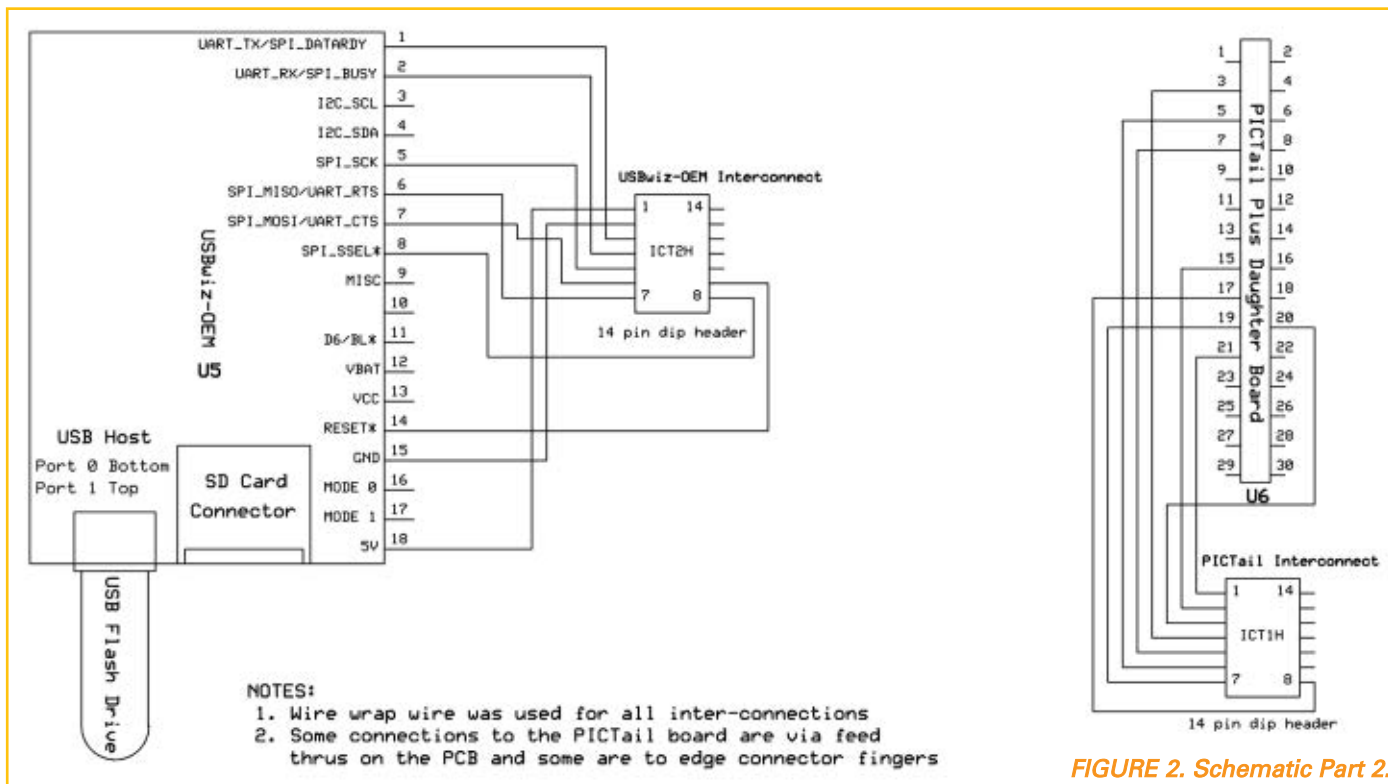


FIGURE 2. Schematic Part 2.

ration file are self explanatory. Table 2 gives the details.

To make configuration changes, remove the Flash drive from the server and connect it to your PC. You can use Notepad to edit the configuration file once the drive is mounted by Windows. After you save your changes, move the Flash drive back to the server and hit the reset button. Webster should come up with the new configuration operational.

Assuming you get the uC programmed, you have wired everything correctly, and a valid configuration file exists, turning on the power should cause the various LEDs to come on, the Flash drive to blink as the configuration file is read, and LED0 to blink about once a second. If all is well, you are ready to connect your server to a network. If you do not see these indications, go back and check your work and try again.

FAT Flash File System

There are a few rules that must be observed for the files and directories that make up website content. The first and foremost is that with the current version (as of November '07) of the USBwiz-OEM firmware, file names must be eight characters or less with a file name extension three characters or less. In other words – like old versions of Windows – only short file names are supported. GHI Electronics is saying that version 3 of their firmware (probably available as you read this) will support long file names. Luckily, the USBwiz firmware is easily upgradeable on the older boards. Note the eight character file name limit applies to

directory/subdirectory names, as well. Actually, the limit is 12 characters but it is unusual to see directory names containing a name, period, and a file extension.

The next rule is that total path length to any file on the Flash drive must be less than 63 characters. Keep this in mind as you organize your data. Too many subdirectory levels can cause Webster to malfunction. Total path length is controlled by the define:

```
// Max path/file name length
#define HTTP_MAX_FN_LEN (64u)
```

in the file HTTP2.h. This number can be increased if it seems too restrictive.

Finally, the configuration file “config.dat” must reside in the root directory of the Flash drive or else it won’t be found on power-up.

Having stated the hard and fast rules that must be followed, I can tell you how I organized the files for my personal website. I put the configuration file and all HTML (.htm actually) files in the root of the Flash drive. This includes a file called index.htm which is the entry point into my website. I then made subdirectories for images and music files. The image files are further organized into subdirectories such as house and woodwork, etc. Basically, images are contained in directories two levels deep. (Notice I said “woodwork” instead of woodworking since it’s more than eight characters and would violate our directory length constraint.)

Using Webster on a Network

Before putting Webster on a network, you must decide if static or dynamic IP addressing is to be used and you must edit the configuration file accordingly. Using DHCP is always easiest if your network permits it. For my website, I connect Webster directly to my wireless router and use DHCP so the router assigns an IP address automatically. This works very well. Once your web server has a public IP address, you must open up the firewall in the router to allow inbound HTTP connections so users outside your network can hit your server. How this is done depends upon your firewall software.

A problem in trying to host a website on a home DSL connection is that the IP address assigned to your DSL router changes under certain conditions. This is a problem whether you are using Webster as your server or a professional product like Apache. Regardless of how you access your website, when your router’s IP address changes, connectivity to your website using an old address will be lost. A solution to this problem that allows one to host a DSL connected website is a program called No-IP. See the Resources for info. The company www.noip.com offers a free dynamic DNS and web redirection service for just this purpose. No-IP will even provide you the use of a domain name from a list of pre-existing domains that you can use for free. Since I am an avid homebrewer, I chose the domain servebeer.com for my use.

The No-IP program runs as a service under Windows

TABLE 2

Configuration Tag	Value	Notes
//	Comment text	All text to the end of the line is ignored.
Hostname:	The name you want to assign to your server	Assigns a name to the server.
Use DHCP:	yes or no (must be lower case)	If yes, the web server gets its IP address from a DHCP server on the network. If no, all of the static entries in the configuration file are used instead.
Use Authentication:	yes or no (must be lower case)	If yes, a user must be authenticated to access the website. If no, the website is wide open. If authentication is being used, the user will be presented with a login dialog box where he/she must specify the correct username and password to gain access to the website.
Username:	The authenticated user’s name (case is significant)	This entry is only important if authentication is being used.
Password:	The authenticated user’s password (case is significant)	This entry is only important if authentication is being used.
MAC Address:	The MAC address of the Ethernet interface	A sticker on the PICTail board contains a number that can be used to form a unique MAC address. When this decimal number is converted to hex, it becomes the last three bytes of the MAC address. My PICTail number was 18423, making my MAC address 00-04-A3-00-47-F7.
Static XXXX:	Static network values	All of the static entries must be filled in correctly if static IP addressing is to be used.

XP. It continually monitors the public address exposed by your router for your web server and informs No-IP's DNS servers of any changes. So as long as access to your website is via your chosen domain name, you are insulated from changes to your router's IP address. By running No-IP on any PC in your network, access to your website will be maintained even if the public IP address of your router/server changes. Pretty slick, huh?

Once you register your web server host with No-IP and your server is operational, you can ping your server with the following command typed into a cmd shell on your PC:

```
ping webster.servebeer.com
```

Executing this command will verify whether my web server, host name webster in the domain servebeer.com is operational or not. You would need to change the ping command for your server in your chosen domain. Once you can ping your server, you should be able to access your website with a browser (Internet Explorer, Firefox, or whatever) by specifying a Universal Resource Locator or URL of the form:

```
http://hostname.domainname
```

If you don't specify a specific HTML file to access, the file index.htm will be assumed. You must make sure a file of this name exists in the root of the Flash drive. Once this works, you are good to go.

Final Thoughts

Webster was fun to design and build, and will help me do my part to conserve energy. Webster is only the first generation implementation of this idea and hence is not as capable as I had hoped. Truth be told, Webster is fine for serving up web pages that are mostly text but suffers when trying to serve rich media like images and music. Webster is like the little engine that could. It tries really hard to push out media rich pages but it takes a while to do so.

Building a one-off of any electronic product is relatively expensive. Building Webster will cost you between \$150 and \$175, depending upon whether you incorporate the

PARTS LIST

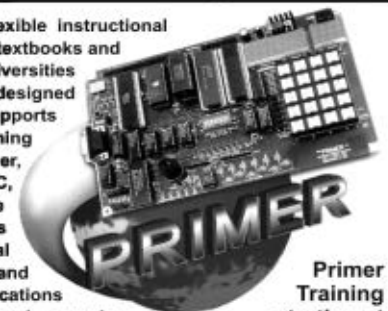
Designation	Value	Notes
■ C1,C2	15 pf	
■ C3,C5,C6,C7,C8,C9,C11,C13	0.1 µF	Bypass capacitors
■ C4,C10,C12,C14	47 µF @ 16V	Electrolytic polarized
■ R1	10K 1/4 watt 5%	
■ R2,R3,R4,R5	470 1/4 watt 5%	
■ J1	Five-pin	ICSP connector (male)
■ J2	Two-pin	Power connector (female)
■ SW1	SPST momentary pushbutton	Reset switch
■ SW2	SPST switch	Power switch
■ ICT1S,ICT2S	14-pin wire wrap sockets	Interconnect socket
■ ICT1H,ICT2H	14-pin component headers	Interconnect header
■ D1	1N4148 diode	
■ D2	1N5819 diode	
■ LED0,LED1,LED2,LED3	LEDs, any color	LED3 optional
■ X1	20 MHz crystal	
■ U1	PIC18LF2620	Microcontroller
■ U2	DLP USB232M-G	Optional <i>see text</i>
■ U3	LM2940CT-5V	Five volt regulator
■ U4	LM3940IT-3.3	3.3 volt regulator
■ U5	USBwiz-OEM	USB host/FAT file system
■ U6	PICTail Plus	Ethernet module
■ USB Flash drive	1 Gbyte typical	Web page storage medium
■ Prototyping board	Rapid28iXL	DHMicro
■ Power supply wall wart	9VDC @ 300 mA or greater	Any manufacturer
■ Wire wrap socket	24-pin	For optional USB232M-G
■ Chassis	Size to fit	
■ Misc. hardware	Screws, nuts, and spacers	For mounting modules

optional USB 232M-G USB client port into your version. I learned a lot from this project that I will use in designing the next generation Webster. So, stay logged in ... **NV**

Craig A. Lindley can be contacted via email at calhjh@gmail.com.

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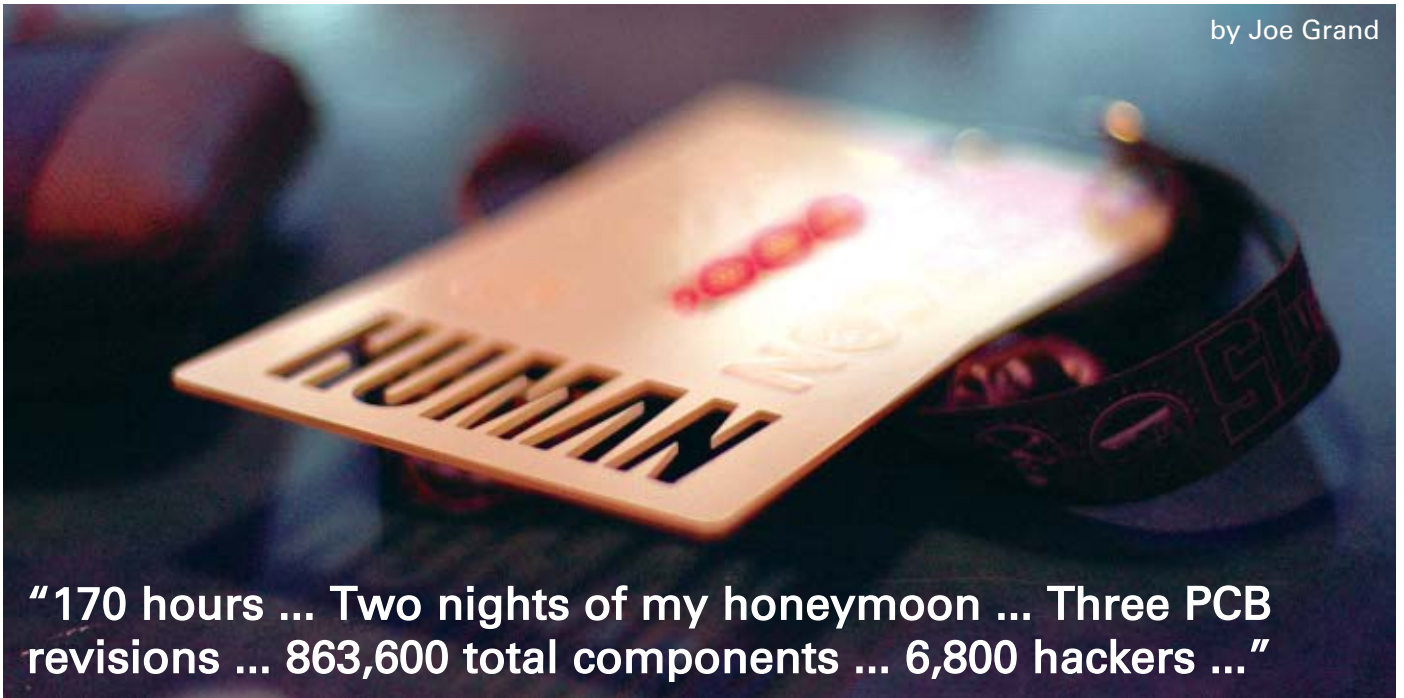
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2390 EMAC Way, Carbondale, Illinois 62901
World Wide Web: <http://www.emacinc.com>

RESOURCES

- Information on PIC processors, the PICTail Plus Ethernet interface (part #AC164123), the free TCP/IP stack, the MPLAB IDE, the MCC18 C compiler, and the ICD2 debugger/programmer can be found at www.microchip.com.
- Information on the USBwiz-OEM board can be found at www.ghielectronics.com.
- Information on the DLP USB232M-G, USB client module can be found at www.ftdichip.com.
- Information on the Rapid28iXL PIC prototyping board is available at www.dhmicro.com.
- Information about the No-IP program can be found at www.no-ip.com.

MAKING THE DEFCON15BADGE

by Joe Grand



"170 hours ... Two nights of my honeymoon ... Three PCB revisions ... 863,600 total components ... 6,800 hackers ..."

Every summer, thousands of hackers and computer security enthusiasts descend into Las Vegas for DEFCON (www.defcon.org) — the largest and oldest continuously running event of its kind. It's a mix of good guys, bad guys, government officials, and everyone in between, all focused on having fun, sharing technical information, seeing old friends, and learning new things.

I've had the honor of designing the attendee badge for DEFCON two years in a row. This article details some of the major trials and tribulations of the DEFCON 15 badge process, from design to manufacture. With this badge (and its predecessor from DEFCON 14, which we don't discuss here), we eschewed the boring plastic or paper badge typical at conferences in exchange for active electronics that actually do something interesting.

Having been involved in the hacker and computer communities for practically my entire life, the challenge of a project like this isn't something I take lightly and it's become a highlight of my career. Hopefully, you'll be able to learn from my mistakes or build on my work to enhance your own projects.

The Goals

The DEFCON 15 badge project was a monumental undertaking, as I only had a few months to design,

prototype, manufacture, and test the badges. There was a real and absolute deadline. Failure would mean that DEFCON would go on without the badge which would be an embarrassment, to say the least. I would do everything in my power to avoid that. In my mind, there was absolutely no other option than to show up with completely functioning badges.

As with any engineering project, it's important to define basic goals and a general design direction to get everyone on the same page before any significant work begins. Unlike some of my other projects, I wasn't working in a vacuum and needed to take input from the DEFCON organizers, add my own flavor, and make sure that everyone involved was happy with the result.

The primary feature that the DEFCON organizers wanted to have was some sort of user-customizable scrolling text message. To support this, the badge would have five operating states:

- 1) Text Message Display
(Default = "I <heart> DEFCON 15")
- 2) Text Message Entry
- 3) Scroll Speed Selection
- 4) Persistence of Vision (POV)
- 5) Sleep

We also defined a set of project-specific goals:

- *Quantity* — The attendance of DEFCON has been going up each year (starting from its humble beginnings of only a few hundred people back in the early 1990s). This year, DEFCON wanted 6,800 badges. For someone (me) who spends the rest of the year designing one-off prototypes to license to other companies, production manufacturing is something I intentionally avoid. Once a year, I give in.
- *Low cost* — The badges had to be cost-effective. The goal was a \$5 to \$7 total BOM (bill of materials) cost per unit including components, programming, PCB manufacturing, assembly, and testing at 6,800 pieces.
- *Hackable* — The badge should have features that would not only allow the attendees to customize or personalize their badges, but be completely "hackable" in nature by providing source code and schematics for those who wanted to modify their badge to do something different and out of the ordinary.
- *Development environment* — All microprocessor development tools (software and hardware) should be available for free or at a very low cost to attendees in order to foster badge hacking.
- *Continued use* — The badge should be designed to provide a general-purpose development environment or reference platform that attendees can build and learn with on their own time after the conference. It's good for the environment, too, by re-using the badge and not just discarding it.

The Design

As I started to piece together the design, going from a high-level block diagram to a prototype to final circuitry, I compartmentalized things into subsystems. Figure 1 shows the schematic for the entire system and Table 1 shows the BOM.

Microprocessor

I chose the Freescale MC9S08QG8 eight-bit microcontroller as the heart of the design due to its excellent integrated feature set, low cost (~\$0.50), low power, easy-to-use development environment, and simple debug/programming port. Freescale's Codewarrior Development Studio toolchain is free for use for projects under 16KB and their USB-based Background Debug Mode (BDM) interface — the SPYDER08 — costs only \$29 each.

Implementing the QG8 microprocessor was as basic as it gets. I just needed to add power (1.8V-3.6V), ground, and connections for the BDM (which I left as an unpopulated six-pin header on the circuit board). I used the QG8's internal oscillator to avoid additional external components, and also since we didn't need high-precision timing. To save power, I ran the clock at 16 MHz during operations and then went into low-power mode as often as possible.

Display

The user-customizable scrolling text and graphics — the keystone of the badge design — are provided via a matrix of 95 LEDs (five columns by 19 rows). I initially looked into using LCDs, but they are hard to read from a distance, fragile, and too expensive. LEDs are common and easy to interface, and Future Electronics was able to find some in an 0603 SMD package for 2.9 cents each (~\$2.75 per badge). Although there are a variety of available LED drivers, none were within my price range or supported so many LEDs. Using three 74HC595 eight-bit shift registers, five current-limiting resistors, and only three I/O lines (along with simple multiplexing functionality in firmware), I was able to control all of the LEDs at only a \$0.35 hit to the total BOM. Each LED in the matrix is individually addressable, allowing users to create custom graphics and animation, and expand the functionality of the scrolling badge.

The three 74HC595 shift registers are connected in series to allow a single shift function to pass data into all three devices (24 bits total). By setting each row of five LEDs in quick succession, the entire display appears visible to the user. A simple function updates the entire display of 19 rows every 8 ms, which was the slowest period that would produce a flicker-free output. Since a maximum of only five LEDs are on at any given time and for only a very short period, average power consumption ended up being fairly low (~6.6 mA while scrolling a text message).

User Interface

I needed a way for the user to switch between the five operating modes and navigate within them. The original plan was to use a Freescale MMA7260QT Triple-Axis Accelerometer, which could be used not only for user interface control, but also as a motion detector that would put the unit to sleep if no motion was detected for a pre-determined amount of time or wake up the unit if motion was detected. The idea was that the user could tilt the badge forwards, backwards, left, or right to scroll through menus and configure his or her device.

While developing with my quick and dirty prototype circuit board (Figure 2), I realized that using the accelerometer just wasn't intuitive enough. Sure, accelerometers are used in all sorts of consumer electronics — like cell phones and video game systems — but none use them as the sole user interface (yet). I decided to get rid of the accelerometer for the primary user input mode and go back to something more simple

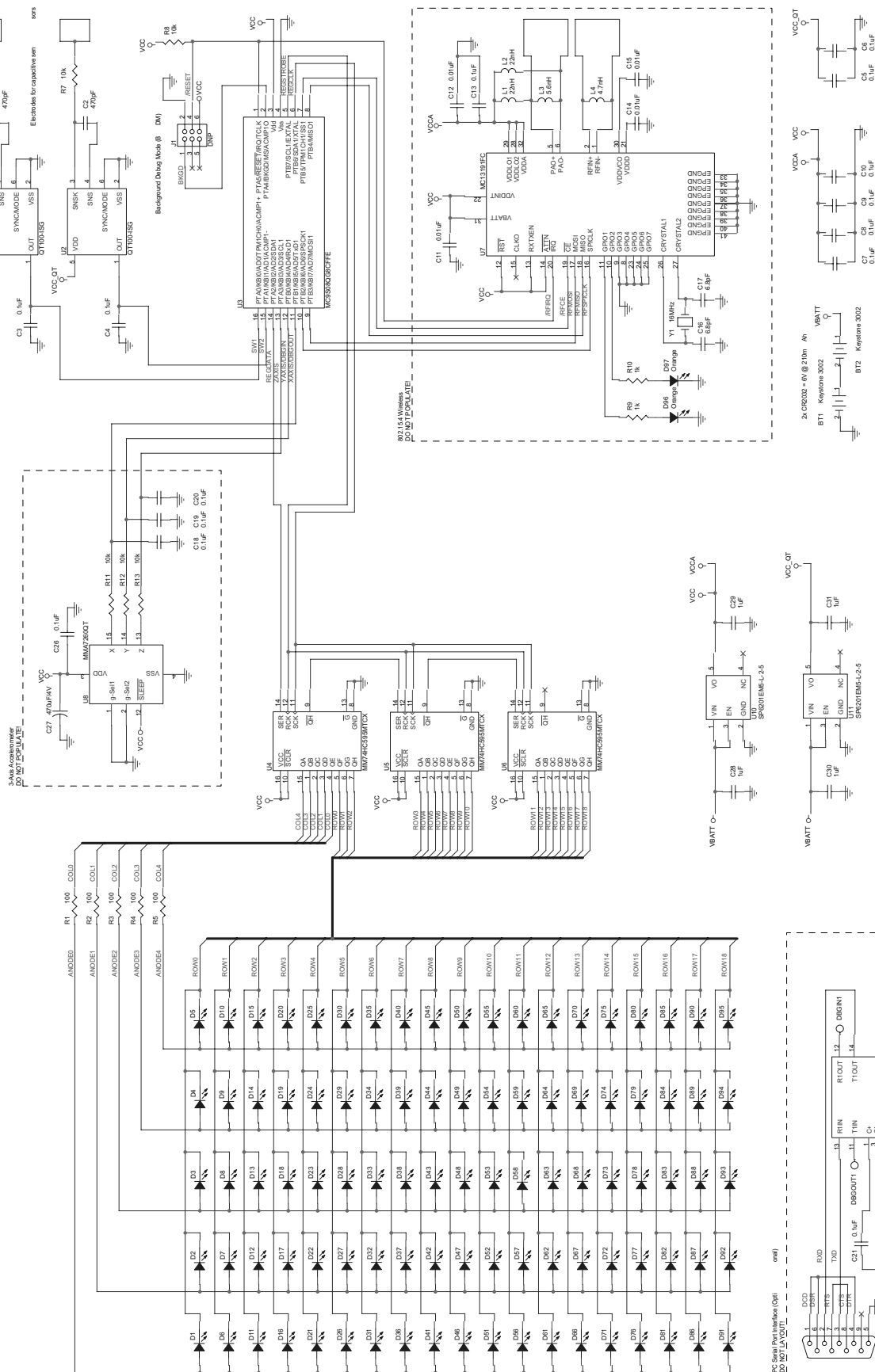


FIGURE 1.
Final schematic
for the
DEFCON 15
Badge.

DEFCON 15 Circuit Board Badge Bill-of-Materials

Item	Quantity	Reference	Manufacturer	Manuf. Part #	Distributor	Distrib. Part #	Description
1	2	BT1, BT2	Keystone	3002	FAI	3002	Battery holder, 20mm coin cell, SMD
1a	2	N/A	Renata Batteries	CR2032	FAI	CR2032	CR2032 Lithium 3V Coin Cell Battery (225mAh)
2	2	C1, C2	TDK	C1608X7R1H471K	Digi-Key	445-1307-2-ND	470pF ceramic capacitor, 10%, X7R (PPS OK), 50V, 0603
3	8	C3, C4, C5, C6, C7, C8, C9, C10	AVX	0603YC104JAT2A	FAI	0603YC104JAT2A	0.1uF bypass capacitor, 16V, X7R, 0603
4	4	C28, C29, C30, C31	Murata	GRM31MR71H105KA88L	FAI	GRM31MR71H105KA88L	1uF ceramic capacitor, 50V, X7R, 1206
5	95	D1-D95	Avago	HSMH-C192	FAI	HSMH-C192	Red LED, 0603, 1.8Vf, 17mcd @ 20mA
6	5	R1, R2, R3, R4, R5	Rohm	MCR03EZJH101	FAI	MCR03EZJH101	100 ohm, 5%, 1/10W, 0603
7	3	R6, R7, R8	Dale	CRCW060310K0JNEA	FAI	CRCW060310K0JNEA	10k, 5%, 1/10W, 0603
8	2	U1, U2	Quantum Research	QT100-ISG	Saelig	QT100-ISG	Charge-Transfer QTouch Sensor, SOT23-6
9	1	U3	Freescall	MC9S08QG8CFFE	Arrow	MC9S08QG8CFFE	Microcontroller, QFN16
9a	1	N/A	N/A	N/A	Arrow	N/A	Microcontroller programming service
10	3	U4, U5, U6	Fairchild	MM74HC595MTCX	FAI	MM74HC595MTCX	Logic, 8-bit Shift Register, TSSOP16
11	2	U10, U11	Sipex	SP6201EM5-L-2-5	FAI	SP6201EM5-L-2-5	Linear Regulator LDO, 2.5V fixed output, SOT23-5
12	1	PCB	e-Teknet	DC15 1.0	N/A	N/A	PCB (includes assembly and testing)

DO NOT POPULATE

802.15.4 Wireless Components

Item	Quantity	Reference	Manufacturer	Manuf. Part #	Distributor	Distrib. Part #	Description
1	4	C11, C12, C14, C15	AVX	0603YC103JAT2A	FAI	0603YC103JAT2A	0.01uF, 16V, X7R, 0603
2	1	C13	AVX	0603YC104JAT2A	FAI	0603YC104JAT2A	0.1uF bypass capacitor, 16V, X7R, 0603
3	2	C16, C17	Murata	GRM1885C1H6R8DZ01D	NewarkInOne	38K1691	6.8pF, 50V, 0603
4	2	D96, D97	Kingbright	KP-1608SEC	NewarkInOne	38K3373	Orange LED, 0603, 2.0Vf, 200mcd @ 30mA
5	2	R9, R10	Any	Any	FAI	CRCW0603-102JRT1	10k, 5%, 1/10W, 0603
6	2	L1, L2	Murata	LQW18AN22NG00D	Mouser	81-LQW18AN22NG00D	Inductor, 22nH, 500mA, 0.17 ohm 0603
7	1	L3	Murata	LQW18AN5N6D00D	Mouser	81-LQW18AN5N6D00D	Inductor, 5.6nH, 750mA, 0.082 ohm 0603
8	1	L4	Murata	LQW18AN4N7D00D	Mouser	81-LQW18AN4N7D00D	Inductor, 4.7nH, 850mA, 0.059 ohm 0603
9	1	U7	Freescall	MC13191FC	Digikey	MC13191FC-ND	RF Transceiver, 802.15.4/ZigBee, 2.4GHz, QFN32
10	1	Y1	NDK	NX2520SA-16MHz	Digikey	644-1059-1-ND	16MHz Crystal Oscillator, 10pF, SMD

3-Axis Accelerometer Components

Item	Quantity	Reference	Manufacturer	Manuf. Part #	Distributor	Distrib. Part #	Description
1	4	C18, C19, C20, C26	AVX	0603YC104JAT2A	FAI	0603YC104JAT2A	0.1uF bypass capacitor, 16V, X7R, 0603
2	1	C27	Sprague	594D477X9004C2T	FAI	594D477X9004C2T	470uF, 4V, tantalum, size D
3	3	R11, R12, R13	NIC	NRC06J103TRF	FAI	CRCW0603-103JRT1	10k, 5%, 1/10W, 0603
4	1	U8	Freescall	MMA7260QT	FAI	MMA7260QT	Accelerometer, 3-axis, adjustable g (1.5/2/4/6), QFN16

PC Serial Port Interface (No Footprints on PCB)

Item	Quantity	Reference	Manufacturer	Manuf. Part #	Distributor	Distrib. Part #	Description
1	5	C21, C22, C23, C24, C25	AVX	0603YC104JAT2A	FAI	0603YC104JAT2A	0.1uF bypass capacitor, 16V, X7R, 0603
2	1	P1	Norcomp	182-099-213R531	Digikey	182-099FE-ND	Connector, DB9 Female, R/A, PCB Mount
3	1	U9	Maxim	MAX3316ECAE	N/A	N/A	RS232 Transceiver, 2.5V, SSOP16

■ TABLE 1. Final bill of materials (BOM).

and intuitive. Like buttons. But, I didn't want to use just ordinary pushbuttons, so I decided to use two Quantum Research QT100 capacitive touch sensors. These units were easy to incorporate and required only a few external components and an electrode area created on the PCB copper layer. When a change in capacitance on the electrode was detected (such as when a person touches it with his or her finger), the QT100's digital output goes high. All processing and debouncing is handled on the QT100, so the microprocessor can simply read the state and determine if the "button" has been pressed.

With two buttons, the user presses one to select which mode they want, uses the other one to enter that mode, and then uses both to navigate within the mode and exit the mode when they're done.

Wireless

As an example of my propensity for feature-creep with this particular project, I thought it would be neat to have the badge support a Freescale MC13191FC 2.4 GHz RF transceiver. Based on the Freescale ZSTAR reference design, the wireless interface was fully designed and incorporated into the final badge circuitry (along with TX and RX antennas created with PCB traces). I intentionally left

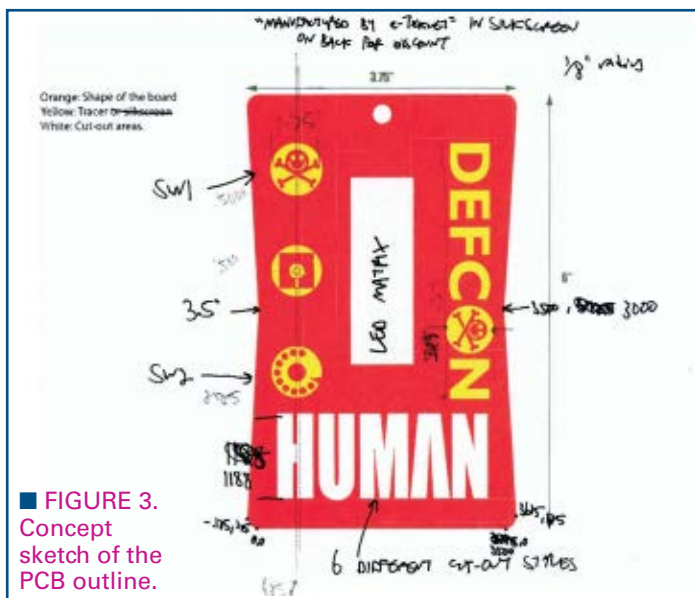
this area unpopulated (primarily due to cost), but this circuitry – coupled with the freely available sample source code from Freescale would allow the badge owner to experiment with 802.15.4, SMAC, or ZigBee wireless interfaces and mesh networking. I gave away about 30 MC13191FC parts at DEFCON in hopes that someone would hack the badge into some sort of wireless system, but no one ever did.

Power Supply and Conditioning

Since this badge (like most any conference badge) needed to be worn around the neck of each attendee, using batteries to power the electronics seemed to be the most logical choice. My first revision of the board simply used a single CR2032 3V Lithium coin cell battery with no additional regulation. The battery voltage was provided directly to all of the components. After encountering a problem with the capacitive touch sensors (details of this are covered later on in the article), I incorporated an additional CR2032 cell in series (for a total 6V nominal) and two Sipex SP6201EM5-L-2-5 low-dropout 2.5V linear regulators. One supply went directly to the QT100 touch



■ FIGURE 2. My initial prototype/development board.



through the weekend (and many more days after that).

Ultimately, battery selection was just another engineering trade-off. Battery life versus aesthetics. I'd be willing to have the badges not last as long in exchange for a much sleeker, cooler looking design.

Circuit Board

Creating the badge electronics was only one part of the battle. The physical badge itself had to visually look nice and professional. It also had to be manufacturable in quantity for a reasonable amount of money. Designing the circuit board would be a perfect opportunity to try some new PCB layout techniques and create a badge that was not only electrically functional, but also artistic.

Starting with a sketch from the folks at DEFCON (Figure 3), I worked with e-Teknet (who was handling our board fabrication and assembly) to determine what features we could add and how to do it in a cost-effective manner. Six different text cut-outs and soldermask colors were used to denote the different DEFCON clientele:

- 1) Human (white), 6,000 pieces
- 2) Goon (red), DEFCON staff, 200 pieces
- 3) Press (green), 125 pieces
- 4) Speaker (blue), 225 pieces
- 5) Vendor (purple), 150 pieces
- 6) Uber (black), Awarded to the winning teams of official DEFCON contests and lifetime entry to future DEFCONs, 100 pieces

I incorporated three icons familiar to DEFCON attendees (the happy face with crossbones, the floppy disk, and the rotary telephone dial) into the design and made two of those icons serve as the electrodes for the capacitive touch sensors. Unbeknownst to anyone else (until the boards came back from fabrication), I had added in a few easter eggs, including a text message (in binary) and GPS coordinates of a historically-important hacker hangout.

During layout, I tried to keep each subsystem compartmentalized, to keep the design cleaner and to make debugging and hacking easier (Figure 4).

The Show Stopper

With all of my development work done on my prototype board (with two QT100 evaluation modules

sensors and the other supply powered everything else.

I decided to use CR2032 coin cells for a few reasons: First, I used them successfully with the DEFCON 14 badge. Second, they were low cost (23.5 cents each). Third, they were low-profile, even when used with a battery holder, and wouldn't look like a big wart on the backside of my badge.

Now, Lithium coin cells probably weren't the best solution for this badge, as they prefer to be used in long-term, low current (< 0.5 mA) applications and typically don't like large drain applications (like my 6-8 mA of the badge at peak operation). The average capacity of a CR2032 cell is 225 mAh to 2.0V under normal drain conditions. But, my conditions were far from normal. Results of my current measurement tests of the final badge design told me that a set of batteries would last only 11.5 hours if the badge was running continuously. If the user put the badge in sleep mode when it wasn't being used, it could easily last



■ FIGURE 4. Final PCB design showing major subsystems.

hand-wired in) and power from a DC supply, getting the first true-to-form PCBs back was my first opportunity for a real-world test and everything initially worked great. The text message on the LED matrix was happily scrolling and all the various modes functioned as designed. But, as my battery life depleted, I noticed some spurious action on the capacitive touch sensors, which caused the badge to change states or enter text when I wasn't even touching it! What was meant to be a clever part of the design by incorporating capacitive sensors instead of boring physical buttons was now an engineering disaster with only weeks to go until we had to start manufacturing.

I immediately started debugging (Figure 5). Using an oscilloscope on the power supply line, I could see that it was very noisy (possibly due to the fast output transitions during multiplexing and/or the varying load on the Lithium coin cells causing the voltage to drop and rise quickly).

As it turns out, the QT100 devices require a very stable power supply (isolated from the rest of the system power) in order to have proper calibration, limited drift, and no spurious detections. The problem only reared its head when I moved from my clean, high current capacity DC power supply to the high current drain averse Lithium coin cells. Somehow, I missed the warning in both the QT100 datasheet and corresponding application note that stated:

*The power supply should be locally regulated and free from spikes, surges, or sags due to other loads. In practice, this usually means that the QT circuit should have its own regulator IC. A regulator IC shared with other logic can result in erratic operation and is not advised. **Failure to heed the warnings in this section have caused designers many lost hours trying to find the cause of sporadic operation.***

Oops.

I added another CR2032 in series with my existing cell to bring the input supply to 6V, then used two 2.5V LDO linear regulators to split the power rails between the QT100s and the rest of the system. Looking at the outputs of the linear regulators, the voltages were nice and smooth (and noise free)!

With the fix figured out, I now had to obtain additional components and update the PCB design to reflect the changes. The timing couldn't have been worse, as I was about to head to Italy with my

wife, Keely, for our honeymoon. To make a long story short, I spent the first two nights of our honeymoon hunched over my laptop until sunrise, putting the finishing touches on the final revision of the badge. Thankfully, I'm still married (and now with a baby on the way!).

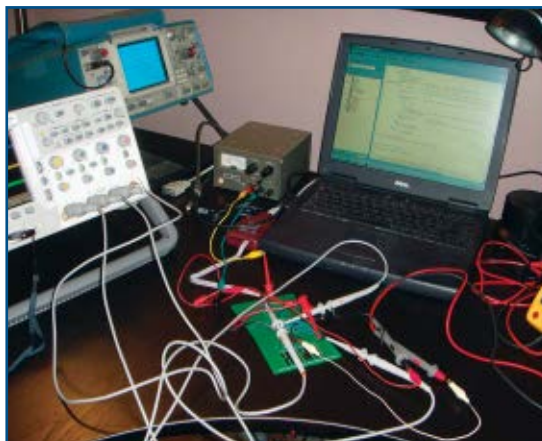
The Procurement

Sourcing and obtaining components for a production build is never easy, as there are so many potential pitfalls along the supply chain. Things like lack of (or misquoted numbers of) available stock, long leadtimes, shipping delays and mishaps, and other human errors have been known to cause electronics production to grind to a screeching halt. Knowing about the finality of our deadline, I tried to leave as much time as possible for any problems and began ordering parts as soon as I'd chosen them for the design. Things like the microprocessor, LEDs, battery holder, battery, and glue logic were ordered with plenty of time in advance.

The parts sourcing went relatively smoothly until those final few days before my honeymoon when I created the fix for the QT100 noise issue. I now needed to obtain 6,800 more batteries and battery holders, and 13,600 low-dropout linear regulators. Thankfully, after a series of frantic phone calls to Future Electronics to determine what parts were available in large quantities at short notice, I was able to select new parts and place an order.

Just as I thought all of my parts procurement troubles were a thing of the past, I was told that the programming house who was supposed to program my firmware into the microprocessors didn't have the proper programming adapter for the QFN package type. Every contact I had was working feverishly to solve the problem, as there were only a few weeks left before DEFCON. Phone calls were made, emails were sent, bullets were sweated. Luckily, Arrow Electronics found the only programming house (at the time; I'm sure that's changed now) in the United States with a QFN adapter and capability to program the Freescale parts. They were able to expedite the programming and have all 6,800 microprocessors back to me in a

■ **FIGURE 5.** Debugging the QT100's sporadic operation issue. There were many other things I would have preferred doing that day.



■ **FIGURE 6.** The six different DEFCON badge styles.





■ **FIGURE 7.** The Badge Hacking Contest area.

matter of days. I've learned to not be caught with my pants down again and, in the future, before selecting a specific microprocessor package, I'll make sure to line up a programming house with the proper resources (or line up a programming house first and select a microprocessor package based on their available resources).

All in all, I had ordered over 863,000 components. There were boxes and boxes of parts stacked high in my garage, ready to ship to e-Teknet's manufacturing facility in China. I was happy to see them go, as it meant another chapter in the design process had been completed.

The Manufacturing

Because of the various development problems and parts sourcing delays along the way, e-Teknet only had four weeks to fabricate the boards, assemble, and test all 6,800 badges, and ship them from China to Las Vegas. That's about 1,700 a week. Or about 250 per day. 250 PER DAY! It took me four hours to hand-assemble a single prototype. If they moved at that rate, the badges wouldn't be done until DEFCON 18. However, e-Teknet would be using an automated process of high speed pick-and-place

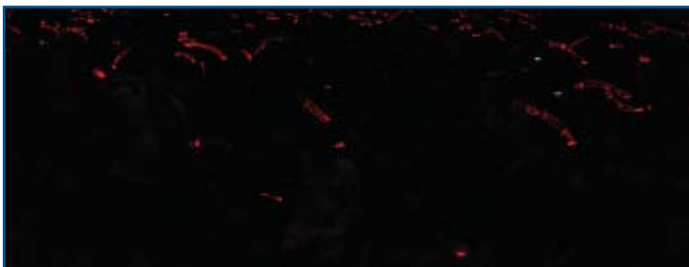
machines and reflow ovens with minimal human intervention (except for those running the machines and handling final test and inspection).

I still didn't feel great

■ **FIGURE 8.** The winning contest entry by Team Osogato.



■ **FIGURE 9.** DEFCON 15 Award Ceremonies. In POV mode, when you wave your badge in one direction, "DEFCON" appears in front of your eyes. (Hard to see in the photo.)



about asking e-Teknet to pull off such a complicated assembly and testing job in such a short amount of time. Leadtime for a project like this would typically run six to eight weeks. e-Teknet essentially had to do it in half the time. They were well aware of the impending deadline and I was communicating with them on an almost daily basis to try and head off any problems. If there was an issue during board fabrication or assembly, it could have taken days to resolve due to language barriers and the time difference between California and China.

Thankfully, e-Teknet was able to pull off the entire manufacturing, assembly, and testing as promised (Figure 6) and started shipping boxes of badges directly to DEFCON as they came hot off the line. They delivered the final batch of badges two days before DEFCON began. My fear of having the badges impounded by U.S. Customs and lost in bureaucratic red tape never materialized and when I peeked into the Las Vegas hotel room used to prepare the DEFCON materials and saw the boxes of completed badges underneath the table, I could finally relax.

The Badge Hacking

Possibly the only thing that went completely according to plan was the DEFCON Badge Hacking Contest. I started this contest a year earlier with a goal of awarding the most ingenious, obscure, mischievous, or technologically astounding badge modification created during the weekend conference. The impetus was simple: Get people excited about electronics, learn something new, teach something new, win prizes. In a world still controlled largely by software and networking, I'm trying to spawn a whole new generation of engineers and hardware hackers. It's a lofty goal, but it's my attempt to give back to the community that I grew up in.

I set up a table in the DEFCON vendor area complete with soldering iron, extra components, and development tools (Figure 7). We even had a real-life engineer from Freescale (thanks Angel!) providing technical support and datasheets, and even gave away dozens of SPYDER08 debugging modules to people seriously interested in hacking the badge.

There were seven official entries in this year's contest, ranging from successful software additions of a real-time clock, Conway's Game of Life, and custom animations, to not-so-successful attempts at hardware modification.

Second place went to Team Slackers (Botten and Dov), who created a single sign-on generator which displayed the password on the badge and worked in conjunction with the Windows-based, open-source pGina user authentication scheme (www.pgina.org).

The winning contest entry from Team Osogato (Len Sassaman, Meredith Patterson,

Dustin Cooper, Martin Murray, Tongen, and Maxinux) was the only one that combined hardware and firmware modifications. The team hacked the badge into a line-level meter for under \$10 in additional components that used the LED matrix to display the peak levels of an audio signal fed into one channel of the microprocessor's A/D (Figure 8). The two capacitive sensors are used to adjust the sensitivity level of the input signal and three shades of "grayscale" are used to create a fading effect on the display. For the icing on the cake, the team worked with The Brothers Grimm (www.myspace.com/CompleteError) to create a rap song based on my Ode to the DEFCON Badge poem that appeared in the DEFCON program (see sidebar). At the Award Ceremonies held at the end of DEFCON, I announced the contest winners by playing their newly created rap song. The house lights were turned off, everyone entered the badge's POV mode, and waved their badges in the air along with the music. It was a sight to see (Figure 9). Team Osogato's entry epitomizes the hacker mentality and goes above and beyond what I had expected to come out of the badge hacking contest. That's what DEFCON is all about.

The End

Despite my going over budget (\$10.73 total BOM cost per unit compared to the original goal of \$5 to \$7), some minor problems with short battery life (as expected based on my power consumption measurements) and spurious "button" presses from the capacitive touch sensing electrodes (as the badge bounced back and forth on the wearer's neck), I'd like to think that the majority of DEFCON attendees enjoyed their badges. Of course, anyone unhappy with the badge should have done the only honorable thing — hack the badge, make it better, and share the results with the rest of us.

The badges would have never been completed without the help of everyone at Freescale, Future Electronics, Arrow Electronics, and e-Teknet. They were instrumental with technical support, component sourcing, manufacturing speed and skill, and going above and beyond the call of duty when handling so many of my urgent problems.

As a side note, the badge was chosen as a Top 10 finalist in Freescale Semiconductor's 2007 Black Widow \$10,000 Design Challenge from a field of more than 775. Can you believe it? A project created by a hacker (the good kind) for hackers had been selected in a mainstream engineering contest. I was thrilled. Even more surprising was that immediately after DEFCON, the badges were selling for up to \$300 on eBay!

I have already started working on the DEFCON 16 badge design. I'm a big advocate of learning from history and I plan on avoiding the pitfalls of last year. Hope to see you in Vegas! Complete source code, schematics, audio, video, and other documentation for the DEFCON 15 Badge is available on my website at www.grandideastudio.com/portfolio/defcon-15-badge/. **NV**

Joe Grand is an electrical engineer and prolific inventor with two granted patents and over a dozen commercially available products. Involved in computers and electronics since the age of 7, Joe has had the fortune of being a member of the legendary Boston-based hacker collective L0pht Heavy Industries, testifying before the United States Senate Governmental Affairs Committee under his nom de hack, Kingpin, and being praised as a "modern day Paul Revere" by the Senators for his research and warnings of computer security weaknesses. Recognized for his unconventional approaches of licensing products developed by his company, Grand Idea Studio (www.grandideastudio.com), Joe is also the author of two books, proprietor of a hacker-inspired apparel line (www.kingpinempire.com), and co-host of an upcoming engineering show for Discovery Channel. He can be reached at joe@grandidea-studio.com.



Ode to the DEFCON Badge

This poem was written for the DEFCON 15 conference program in lieu of a boring instruction manual. Thankfully, I'm a better engineer than poet, but I think it does the job.

170 hours of total time spent
2 nights of my honeymoon (oh, how I lament!)
3 circuit board revisions to get it all right
863,600 total components bring them to light
6,800 hackers wearing the badge in all its glory
If you want to learn more, please read this fine story

A matrix of 95 LEDs (5 columns by 19 rows)
Two coin cell batteries make the current flow
Six text cutouts and soldermask colors to show
If you're a human, speaker, goon, vendor, press, or uber bro

On power up the badge will not make a peep
But fear not, that's by design, it is only asleep
Touch the top icon (it's a button, really)
And get a scrolling text message intended for thee

Touch the top icon yet again (just trust me)
And you'll move to the next mode for custom text message entry
Hit the bottom icon to begin your noble quest
Then use either icon to cycle through the list
Tap both icons to save a character to your queue
16 letters long is the maximum we can do
When you're all done, seek out the solid block
Tap both icons again and on the screen your message will walk
The next mode sets the speed of your inscription
You can change it like a baud rate or a doctor's drug prescription
Select the scroll velocity between the numbers 1 and 5
Which goes from slow and boring to a thrilling autobahn drive
(Remember to tap both icons for the badge to come alive)

Next we arrive at our last badge state (finally)
A special treat known as persistence of vision or POV
Wave the badge in front of your eyes in one direction
And a secret message appears magically like the morning's first erection
If all you see is a jumbled mess of bright lights
Try hiding in the darkness, squinting your eyes, or changing those
hard-coded bytes
(When your badge is not in use, set the mode back to snooze)

The source code is open and the schematics are free (as in beer)
So now you can be a hardware hacking engineer
Unpopulated footprints for a wireless transceiver and accelerometer
If you don't like how the badge acts, then hack it and make it better
(You might even win some development tools, a T-shirt, or a scarlet letter)

For the blood, sweat, and tears behind the scenes of the DEFCON badge
Come to my talk on Friday morning, it's sort of like the hajj (okay, not really)
Business in front, party in back (yeah, that's a mullet)
I'm Joe Grand aka Kingpin from the L0pht, a hacker not a poet

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logic input states (ABCD) to one of 10 (0-9) available output logic states. Decoding octal values only requires logic input states

on the least significant three bits (ABC) of the CD4028's four available bit inputs. For instance, binary 0000 (arranged DCBA) at the input of a CD4028 will result in binary 0000000001 (arranged 9-0) on the CD4028's 0 (zero) output pin. Binary 0001 will result in an output of 0000000010 on the CD4028's 1 output pin. Only outputs 0 through 7 are valid octal outputs. Any input greater than 7 is an invalid octal number. That's why the CD4028's most significant D input must always be zero when decoding octal numbers. BCD (Binary Coded Decimal) decoding uses

continued on page 89

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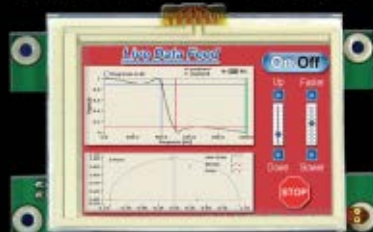
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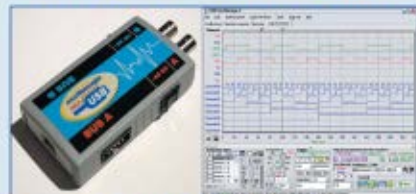
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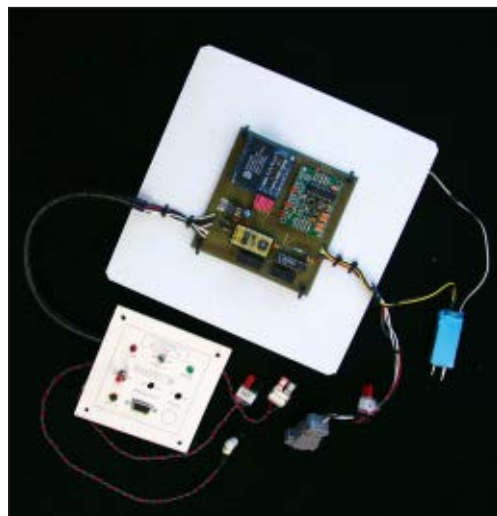
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■ BY L. PAUL VERHAGE

THE NEARSYS FLIGHT COMPUTER

MY FIRST NEAR SPACE FLIGHT COMPUTER transmitted all of its data to ground stations and recoded none of it onboard. As a result, I had a huge mission log to wade through and edit after each flight. It got so bad that it took longer to put the flight and science data into shape than it took to fly the mission. So this month, I'll introduce you to the flight computer that I'm currently using to operate my near spacecraft. It avoids these problems by transmitting only position reports to ground stations and processing and recording the rest of the data onboard for later retrieval.



THAT'S SO 20TH CENTURY

In preparation for my first near space mission in 1996, I designed a flight computer to digitize sensor voltages, operate external devices, format data packets for transmission, and control the GPS receiver's access to the radio. All the near spacecraft data, science data, and GPS position reports were transmitted at the standard APRS frequency of 144.390 MHz. Since the tracking crew used the same frequency to communicate with each other, the log I received after each mission consisted of something like 5% my data and 95% chase crew position reports. Sorting through the log took hours as I checked each line of text and deleted those of the chase crews. And deleting their text was just the start; I

NOTE: All PCB patterns and files are available on the *Nuts & Volts* website at www.nutsvolts.com.

still had to format the data into a form that a spreadsheet would accept.

After a few years of editing these massive log files, I decided I had to record science data onboard the near spacecraft and avoid contamination by the chase crew. Since my near spacecraft spends very little time actually creating data (a few seconds each minute), the flight computer would have plenty of time to format and store its data the way I wanted. The result is that after a mission, I could spend less than an hour processing my mission data and creating charts.

THE BLOCK 3 NEARSYS FLIGHT COMPUTER

I've always designed my near space flight computers around the BASIC Stamp 2 IC (BS2). However, creating an improved flight computer would require more memory and better serial data handling capability. Therefore, I began looking at other microcontrollers, like Tiny Tigers and

Rabbits, as a replacement for the BS2. However, before wading too deeply into these new microcontrollers, Parallax released BASIC Stamp 2p (BS2p). After reading its specs, it became obvious that the BS2p would be ideal as the heart of a new flight computer. The eventual design — incorporating a BS2p, MAX186, RAM Pack B (RPB), and TinyTrak3 (TT3) — was called the NearSys Block 3 Flight Computer (the block 1 and 2 models are detailed in my near space book at the Parallax website; www.parallax.com).

THE BS2P AND ITS SCRATCH PAD

Two features caught my eye about the BS2p. First is that it has additional EEPROM, eight 2K memory slots instead of just one. There were instances where I had to reduce the functionality of a flight program because the BS2 ran out of memory. With the BS2p's additional memory, programs can be

divided into functional blocks and stored in separate memory slots. The careful use of RAM allowed different memory slots to share variables. And in a way, the BS2p behaved like it had 16K of continuous EEPROM. If you're not familiar with the BASIC Stamp, EEPROM is the memory where programs (and occasionally data) but not variables are stored.

Along with having additional memory for programs, the BS2p also has a scratch pad memory. The scratch pad is 128 bytes of RAM that's available to all program slots. But best of all, it is memory that serial data can be read into. By first saving an entire GPS sentence into RAM, the BS2p has plenty of time to pick out (parse) the bits of GPS data it needs.

Typically, I program the BS2p to record the time and altitude from the GPGGA sentence and the speed and heading from the GPRMC sentence.

The other nice thing about the scratch pad is that it allows large data records to be assembled one byte at a time. A data record contains all the data the flight computer collects each time it loops through its program. Typically, a data record consists of data from the GPS receiver, digitized analog sensor voltages, the results of digital experiments (like the number of cosmic rays detected in a 10 second period), and special messages. Where does the assembled data record go? After all, the scratch pad will be reused to assemble the next data record. The assembled data record is dumped — one byte at a time — into long term storage (the RAM Pack B). After a pause, the BS2p begins the process over again of collecting flight data, building a record, and recording it into storage for retrieval after recovery.

MAXIM IC'S MAX 186

Many of the sensors I launch into near space produce data as changing voltage levels (usually between 0 and 5 volts). The BS2p cannot deal with analog voltages directly, so the flight computer contains an analog-to-digital (A-to-D) converter. I use the MAX186, a low power eight channel

serial 12-bit A-to-D converter from Maxim IC. The MAX186 is limited to a maximum voltage of 4.096 volts and since 12 bits of resolution has a maximum value of 4096, the MAX186 is capable of digitizing voltages to a precision of one millivolt.

RAM PACK B BY SOLUTIONS CUBED

Since the flight computer isn't transmitting data to the surface, data must be stored onboard. One way to store data is to use an EEPROM program slot on the BS2p. However, this limits the mission data to a length of 2K (unless I use more than one of the slots). Instead of using Stamp EEPROM, I elected to use the RAM Pack B (RBP).

The flight computer adds data to the RBP in FIFO mode. This way, the BS2p doesn't have to keep track of memory addresses. Once set up in FIFO mode, the RBP accepts bytes sent over its serial link and stores them in successive memory locations. The RBP comes with a socketed 8K static RAM chip that requires power to maintain data.

Since the flight computer is powered down after recovery, the SRAM was replaced with a Dallas DS1230 32K non-volatile RAM (NVRAM) IC. Recently, the RBP has become obsolete. So you'll need to have one in your parts box or order one from eBay.

BYONICS AND THE TINYTRAK3 (TT3)

The TT3 is a modem for amateur radio. Its onboard PIC microcontroller takes serial data from a GPS receiver and converts it into tones for transmission over amateur radio at a speed of 1200 baud. To do this, the TT3 keys the radio by activating its press-to-talk (PPT) button and produces a series of two tones of 1,200 and 2,200 Hz. A change of tones signifies a digital zero and no change in tone signifies a digital one. The flight computer doesn't require all the parts in the TT3, so it's purchased in kit form and only partially assembled.

The flight computer is designed such that the GPS transmits data directly to both the TT3 and BS2p (I/O pin 11).

THE TINYTRAK3 AND GPS RECEIVERS

Most GPS receivers transmit data in the NMEA-0183 format (NMEA is the National Marine Electronics Association and they set industry standards for the interoperability of marine equipment). In that format, there are over a dozen standard data formats called sentences that a GPS receiver is likely to use. The two important ones for the TT3 are the GGA and RMC sentences. These sentences are formatted as shown in the examples below:

Fix Data (the GGA Sentence)

\$GPGGA,123456,4412.304,N,09612.276,E,1,05,0.9,18123.6,M,45.2,M,,*48

The fields in the GGA sentence are: Time (in UTC); Latitude (in degrees and minutes); N (for North); Longitude (in degrees and minutes); E (for East); Quality of GPS fix (1 is a good fix and 0 is no fix); Number of satellites being tracked; Dilution of Horizontal Precision (the closer to 1, the better); Altitude (in meters); Height of the Geoid (how much the earth's surface deviates from a sphere in units of meters); Two fields of differential GPS information (not normally used on a near space mission); and a checksum.

Recommended Minimum Sentence C (the RMC sentence)

\$GPRMC,123456,A,4412.304,N,09612.276,E,013.2,123.4,190408,012.4,W*85

The fields in the RMC sentence are: Time (in UTC); GPS status or warning (whether the GPS is active (A) or if its data is void (V)); Latitude (in degrees and minutes); Longitude (in degrees and minutes); Speed over the ground (in knots); Heading (in degrees true North); The date (day, month, and year); Magnetic variation (in degrees true North); and a checksum.

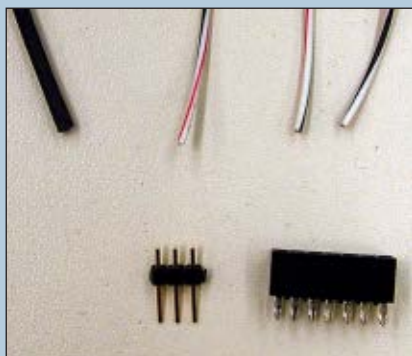
The TinyTrak3 combines fields from these two sentences to create a position packet looking like this.

KD4STH-9>APT310,WIDE3-3:I4305.04N/11507.68W>219/004/A=068640/Flight Computer 3

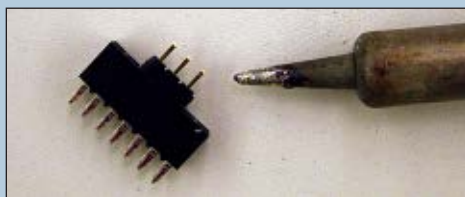
The fields of the TT3 position report are: Callsign> Path,Path!Latitude N/Longitude W>Heading (true North)/Speed (knots)/A=Altitude (feet)/Optional Message.

CABLE CONNECTORS

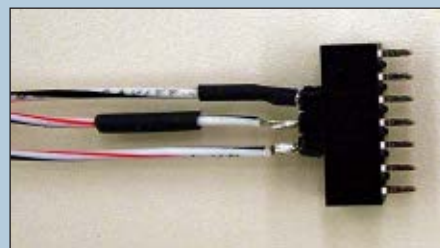
Here — in just three pictures — is how I like to make cable connectors for the flight computer:



■ You'll need a three-pin header, receptacle, wires, and thin heat shrink.



■ Before bringing the soldering iron anywhere near the three-pin male header, plug the longer leads of the header into a receptacle. Then, tin the short pins of the header and the wires of the sensor cable. By inserting the header into a receptacle, the header's pin positions will be protected from distortion by the heat of the soldering iron.



■ After tinning the leads and header pins, slide short lengths of heat shrink tubing over the wire, then solder the wire to the header pin. After the solder cools, slide the heat shrink over the exposed soldered connection and shrink the tubing.

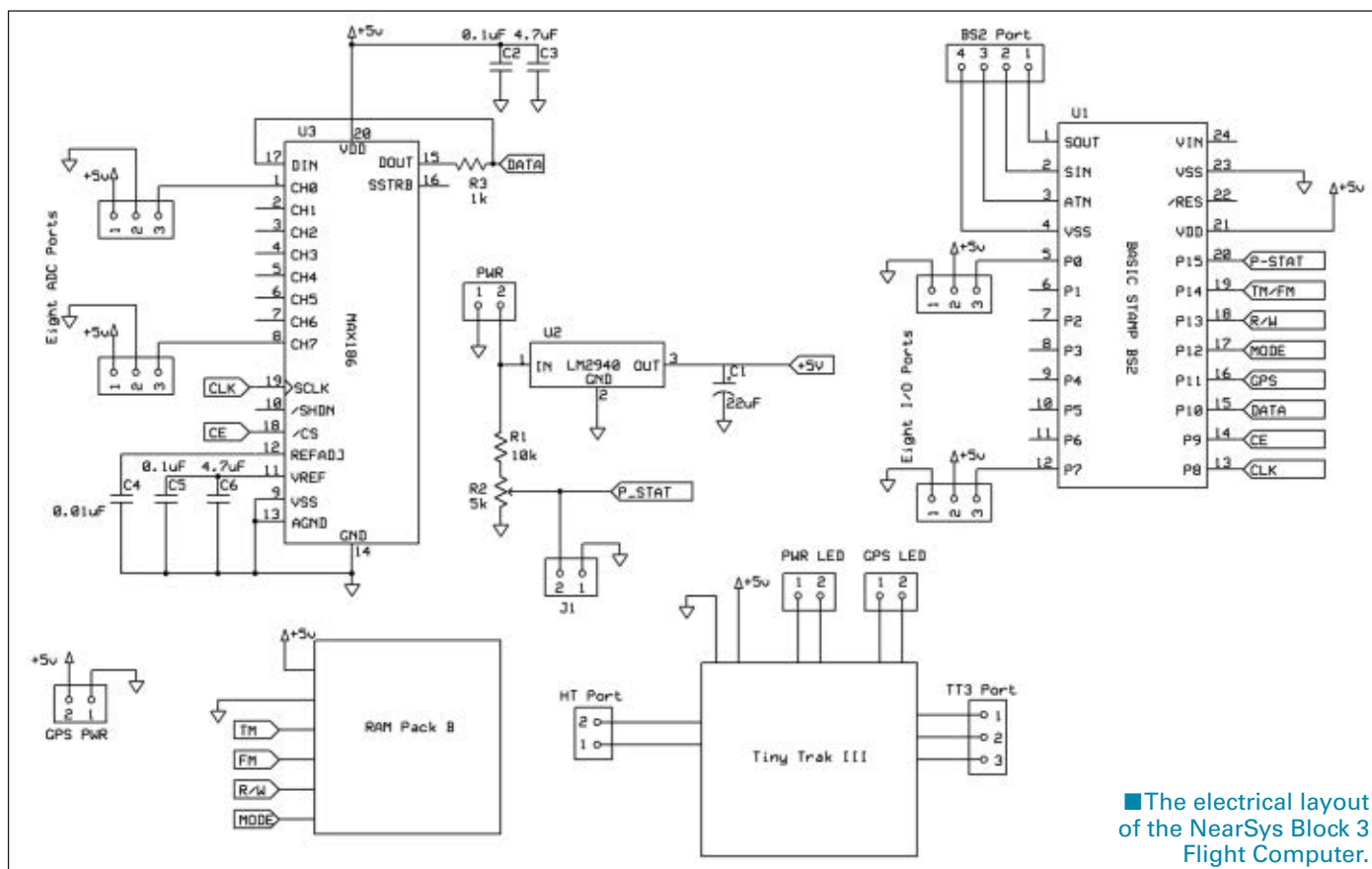
The BS2p records some GPS data and uses it to determine if the balloon is ascending or descending (that way, the flight computer can close experiments during descent). As a safeguard against a BS2p coding error, the TinyTrak3 gets its position reports directly from the GPS and transmits them to ground stations. The BS2p does not interfere with this process.

PUTTING IT ALL TOGETHER

Two PC boards, the TT3, and the RPB bolt to the flight computer PCB (printed circuit board). Instead of using stand-offs, I prefer to mount the boards on top of a sheet of Foamies. Foamies is an expanded neoprene rubber

(foam rubber sheet) and available from many craft stores. By using Foamies and bolts in place of stand-offs, the mounted PCB is supported across its entire surface and there's no open space beneath the PCB where loose wires or bolts could collect.

Sensors are connected to the MAX186 and BS2p through eight rows of three-pin receptacles. Each



■ The electrical layout of the NearSys Block 3 Flight Computer.

BS2p three-pin receptacle is organized like a servo connector, signal, +5 volts, and ground while in the MAX186 the power and ground positions are swapped so it's easy to short unused inputs. This style of connection simplifies interfacing to the flight computer because each cable terminates in a three-pin header that supplies signal, power, and ground to the experiment.

The voltage regulator is a low dropout LM2940T-5. It's folded back and bolted to the flight computer PCB to give it a heatsink. I've observed that LM2940 can operate the flight computer and its GPS receiver down to a supply voltage of 5.3 volts. I suppose

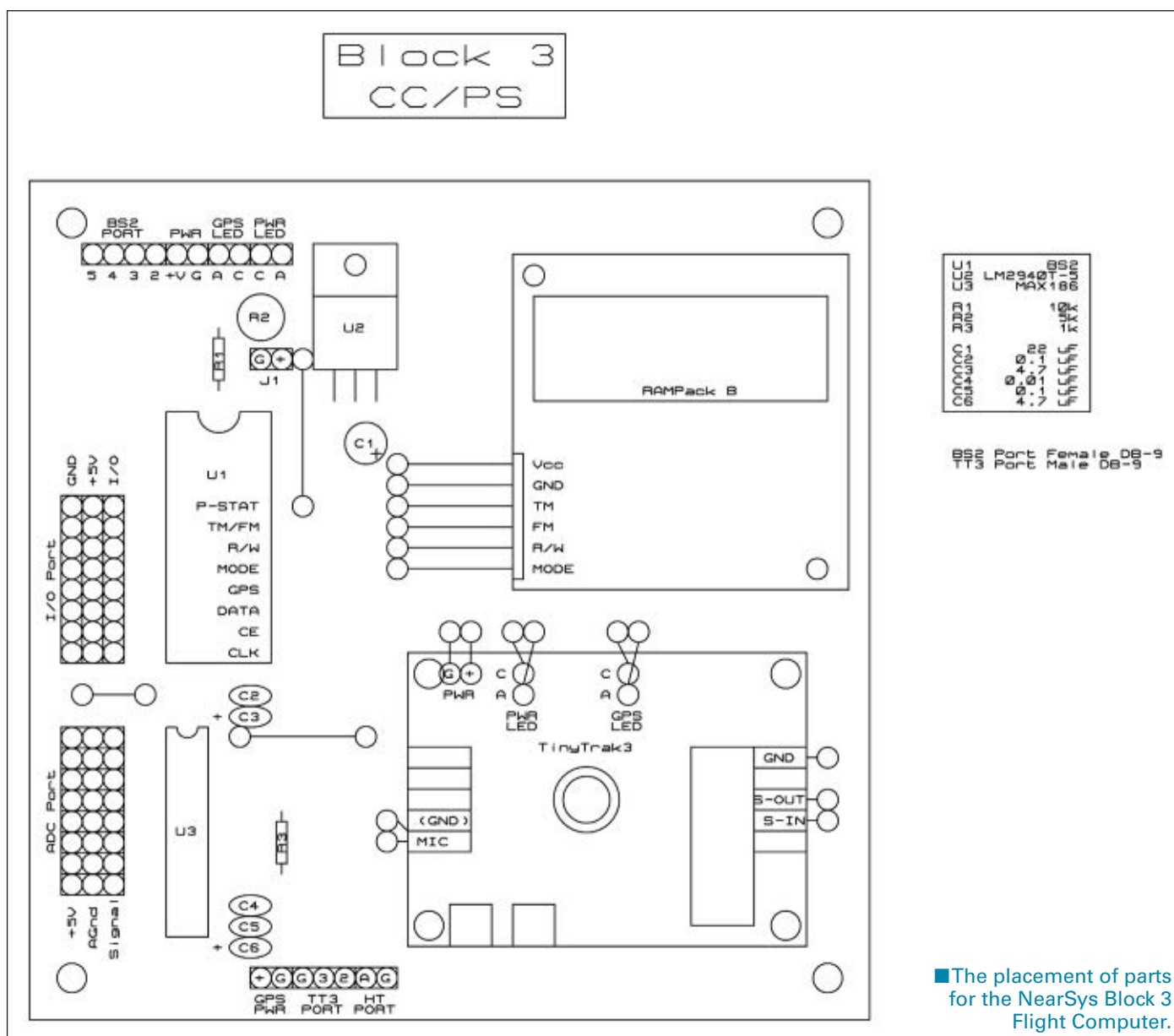
the limiting voltage will be lower if the current requirements are larger.

Resistors R1 and R2 form a voltage divider circuit allowing the BS2p to monitor the main supply voltage. The output of the voltage divider goes to BS2p I/O pin 15 (called P-STAT or power status). Although not yet implemented, this feature allows the BS2p to terminate its mission should the supply voltage drop too low. Since a voltage of 1.4 volts or less appears as a logic low to the BS2p, the voltage divider is set to create a 1.4 volt drop shortly before the supply voltage to the PCB drops to 5.3 volts. Since R1 is fixed at 10K, the center tap of trimmer R2

must be adjusted for about 4K.

None of the LEDs, its voltage regulator, or the two DB9 connectors are attached directly to the TT3 PCB. Instead, two of the LEDs (power and lock), two pads of the voltage regulator (ground and +5V), and the DB9 pads connect directly to the flight computer through jumper wires.

The TT3's power and lock LEDs instead connect to cables soldered to the flight computer PCB. This way, they can be routed to a power and display panel on the side of the near spacecraft airframe. Only the TX, RX, and GND pads of the TT3's serial DB9 pads connect to the flight computer. Like the LEDs, the serial DB-9 header



Great Plains Super Launch

It's time for the Great Plains Super Launch (GPSL)! GPSL 2008 is in Kansas City from July 31st to August 3rd. This year's sponsor is Near Space Ventures and CAPnSPACE. Here's the mission of GPSL as described in its website: "The Great Plains Super Launch is the premier conference for near space explorers and enthusiasts dedicated to the education and study of aerospace science via Amateur Radio High Altitude Ballooning."

If you'd like to become a near space explorer or are just an enthusiast, then plan to attend this year's event. Check the official website for up-to-date information at www.superlaunch.org. Admission is free and open to the public. Be sure to look me up when you get there.

connects to wires in the flight computer PCB. The TT3 is programmed and receives GPS data through its serial DB9 header. Since the TT3 is programmed through a serial cable with a male DB-9 connector and receives GPS data over a serial cable with a female DB-9 header, a gender changer is needed to program the TT3.

The amateur radio connects to the TT3's other DB-9 connector. Only two pads of this DB9 are soldered to the flight computer. The reason that only two are needed is that the TT3 is not using its Hold Off feature. Hold Off prevents the TT3 from transmitting a position report if the radio frequency is busy with other radio traffic. This could

be a problem during a mission because the onboard radio will hear radio signals from over 300 miles away. Therefore, in near space, the Hold Off can prevent the TT3 from transmitting position reports for reasons the chase crews cannot hear. Besides, the near spacecraft is usually worth more than \$500 and flying at 85,000 feet. I think this gives it priority over ground stations.

The RPB is a completely assembled PCB. Therefore, mount it with the flight computer PCB with Foamies and bolts and then solder it to the PCB using tinned resistor leads. When I first assembled the Block 3 flight computer, I was concerned that the wires of the RPB would short against each other during a mission. So, you'll see in the photo at the beginning of this column that I used insulated wires instead of resistor leads to solder the RPB to the flight computer.

The main power cables I use are Anderson Power Poles. You don't have to use the same connectors, but you should select a standard connector and use it for all your near space electronics. If you choose to use the Andersons like I did, then back fill the connectors with hot glue after snapping in the terminals. The hot glue makes the connectors stronger while providing protection from electrical shorts.

How you connect the radio to the flight computer depends on the amateur radio (HT) you use. There's documentation with the TT3 covering different radio connections. Your radio connection will probably use two separate connectors like 1/8 and 3/32 inch stereo plugs. After making these connectors, I like to glue them into a single plug with thin plastic, hot glue, and heat shrink.

After completing the flight computer, mount it to a sheet of Correplast with Foamies and zip-ties. Correplast is a corrugated plastic that's rigid and lightweight. Since the PCB doesn't have strain relief, add a cable strain relief by zip-tying the flight computer's cables down to the Correplast.

I've made one of my flight programs available on the *Nuts & Volts* website (www.nutsvolts.com) along with the downloading software I use to retrieve flight data after the near spacecraft is recovered, and the overwriting program I use to erase old data before a mission. You'll see I have an unusual subroutine to convert the binary values from the ADC into ASCII text. This is required so that a terminal program can properly display the mission's collected data.

If you have a TinyTrak3 and a spare RAM Pack B, try your hand at building the NearSys Block 3 flight computer. After I settle into my new career as a student, I'll start designing the Block 4 version that includes new features. As soon as it's done, I'll share it with *Nuts & Volts* readers.

Onwards and Upwards,
Your near space guide **NV**



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USEFUL WEBSITES

- TinyTrak3: byonics.com/tinytrak
- RAM Pack B: www.solutions-cubed.com
- MAX-186: datasheets.maxim-ic.com/en/ds/MAX186-MAX188.pdf
- BS2p: www.parallax.com
- Materials for making printed circuit board: DALPro.net

Note: If you'd like to make your own printed circuit boards from the copper patterns included in this column, consult my article in the January 2001 issue of *Circuit Cellar*. By following its directions, you could make your own high quality PCBs at home faster and cheaper than a board house will charge.

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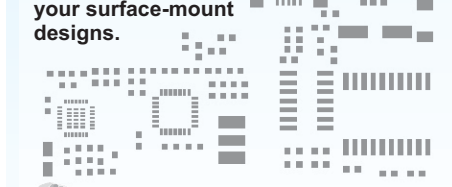
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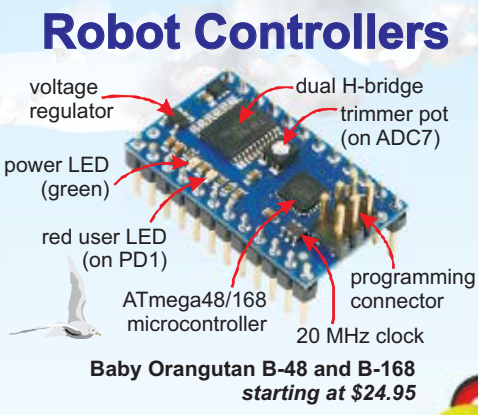
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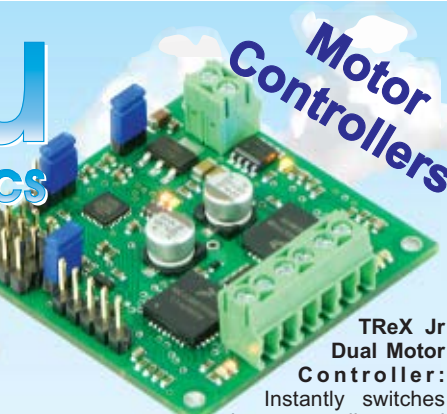
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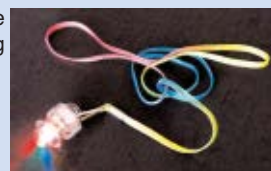
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GETTING STARTED WITH PICs

THE LATEST IN PROGRAMMING MICROCONTROLLERS

■ BY CHUCK HELLEBUYCK

MONITORING INPUT SIGNALS

I KNOW I'VE HIT ON THE RIGHT TOPIC when the amount of email increases. As soon as readers started getting their May issues of *Nuts & Volts*, the email started to roll in with overall great feedback. I had several people email me looking for help getting microEngineering Labs' (melabs) PICBASIC™ PRO and Microchip's MPLAB® IDE working together, which was the topic of my column in that issue. This just further indicates to me that readers do follow along and try out what I present, and that makes me want to keep growing this column with the reader. For example, one reader simply forgot to add the directory paths required, as described in the MPLAB IDE setup website <http://melabs.com/support/mplab.htm>. Another reader substituted the letter O for the number zero in one of the register names, and got an error they could not find. These are common errors anyone can encounter, but often can be deal breakers to a beginner trying to learn embedded microcontroller (MCU) development. Don't let items like these get you down — most experienced programmers have been there. Getting past these little steps is a direct path to becoming an experienced developer of MCU-based electronics.

In this month's column, I want to introduce a common topic involving sensing or measuring input signals. A wise, experienced engineer recently suggested I point out that all MCU projects involve three basic parts:

- 1) Power and Ground
- 2) Inputs
- 3) Outputs

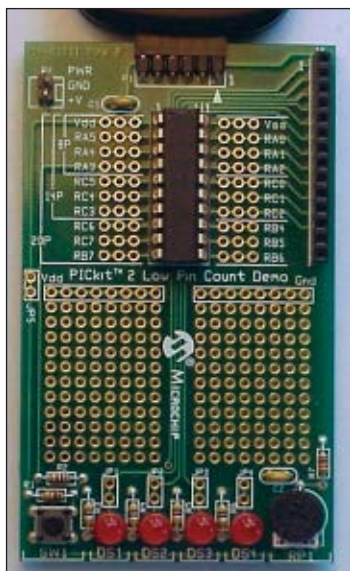
He's right — it really is this simple. In May's column, I showed how to get the MPLAB IDE and PICBASIC PRO working together using the simple example of making an LED light up and flash. That was an example of a digital output, and it could be more than an LED. The

LED could be a relay or transistor that controls a motor or some other output device. Outputs are typically digital, on or off, but there are exceptions such as pulse width modulation (PWM) or digital-to-analog conversion. There are also two types of inputs: digital and analog. I intend to cover the blinking LED equivalent of these in this month's column.

DIGITAL INPUT

All MCUs operate as digital devices, meaning they see things as true or false, or signals as high or low. This is typically represented as a 1 or 0, numerically. This is a digital input, which often fits well in the real world. A pushbutton switch, for example, can be monitored to see whether it was pressed. This is an example of a digital input. Reading a switch is a common project requirement that may be used to turn something on or off, or to select a different mode. The Microchip PICkit™ 2 Starter Kit

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■ **FIGURE 1.** PICkit™ 2 Low-Pin-Count development board.

(which I've used in previous articles) includes a development board that has a momentary pushbutton switch designed in. The board is called the Low Pin Count development board, and is shown in Figure 1.

The switch on this board is labeled SW1, and is wired with a pull-up resistor to create a high signal when the switch is idle, and a low signal when the switch is pressed. The software just needs to read the port connected to the switch to determine whether the signal is high or low and then react accordingly. The full schematic of the board comes with the PICkit 2 Starter Kit. The switch portion of that schematic is shown in Figure 2.

Unfortunately, the switch SW1 was designed to act as a reset switch and not a general-purpose input switch. I say this because it is connected to the RA3 pin of the PIC16F690 MCU. The RA3 pin is also the MCLR pin or master clear pin for the PIC16F690. When the external MCLR operation is enabled, this MCLR pin can reset the PIC16F690. You can think of it as the Ctrl-Alt-Delete key for the PIC16F690. This pin is also multiplexed with the VPP pin, which is the programming voltage pin used by the PICkit 2 programmer to put the PIC16F690 into programming mode. The pin can be configured as a digital input pin, as well. All these options make using this built-in switch a little more difficult for a beginner application, but I'll step you through it so you get past another small hurdle.

SWITCH SOFTWARE

I'll once again use the sample version of the popular PICBASIC PRO compiler to write a simple switch monitoring routine. I'll create the project using the MPLAB design environment covered in the May 2008 column. The code snippet to read the switch is shown in Listing 1.

HOW IT WORKS

The LEDs on the board are connected to the PORTC pins RC0 through RC3. The switch is connected to PORTA pin RA3. The software starts off by initializing the PIC16F690 MCU's internal registers. We are reading a digital signal, so the analog-to-digital (A/D) ports need to be set to digital mode. The PIC16F690 defaults at reset to A/D mode. We set them all to digital mode by clearing the ANSEL register. The comparators are also not used, so it's best to turn those off. We do that by clearing the CM1CON0 and CM2CON0 registers.

The TRISC register controls the direction of the I/O for PORTC, so setting TRISC to zero sets all PORTC

pins to outputs. Setting TRISA to all ones (\$FF hex or %11111111 binary) makes all of PORTA inputs. Finally, the PORTC register is set to all zeros to make all the PORTC outputs low, thus keeping the LEDs off.

` Initialize Internal Registers

```
ANSEL = 0           ` Initialize all A/D pins to
                    ` digital
CM1CON0 = 0         ` Initialize Comparator 1 off
CM2CON0 = 0         ` Initialize Comparator 2 off
TRISC = 0           ` PORTC all outputs for LEDs
TRISA = $FF         ` PORTA all inputs for switch
PORTC = 0           ` Preset LEDs off
```

The main loop of code uses the IF-THEN command to test the RA3 pin for a low condition or zero, indicating the switch was pressed. Switches have spring metal inside that can bounce like a car without shock absorbers, so we need to address that. Adding a 100 millisecond delay and then reading the switch port again forms a very simple debounce routine to bypass this switch bounce potential. Switch bounce can make the software think multiple switch presses occurred.

*** Main Program Loop ***

Main

*** Read State of Switch with 100 msec Debounce

```
if PORTA.3 = 0 then    `Switch is pressed
    pause 100          `Delay 100 msec

if PORTA.3 = 0 then    `Test switch again
```

LISTING 1: Software to read switch SW1.

` Initialize Internal Registers

```
ANSEL = 0           ` Initialize all A/D pins to digital
CM1CON0 = 0         ` Initialize Comparator 1 off
CM2CON0 = 0         ` Initialize Comparator 2 off
TRISC = 0           ` PORTC all outputs for LEDs
TRISA = $FF         ` PORTA all inputs for switch
PORTC = 0           ` Preset LEDs off
```

*** Main Program Loop ***

Main

*** Read State of Switch with 100 msec Debounce

```
if PORTA.3 = 0 then    `Switch is pressed
    pause 100          `Delay 100 msec
```

```
if PORTA.3 = 0 then    `Test switch again
    High PORTC.0       `Light LED DS1
```

```
hold
    if PORTA.3 = 0 then hold `Wait for
                        `switch to be
                        `released
endif
```

```
endif
```

```
Low PORTC.0           ` LED DS1 off
```

```
goto main             ` Loop back
```

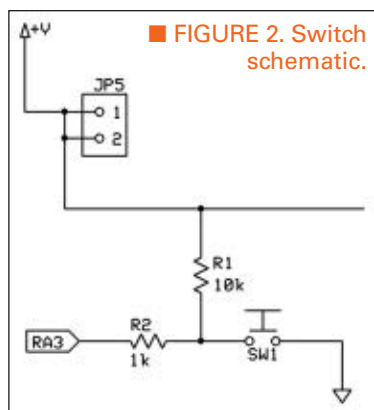


FIGURE 2. Switch schematic.



If the switch was pressed and made it through the debounce, then the PORTC pin zero is set high to light the DS1 LED on the board. An IF-THEN command is used to continue testing the switch and will put the program in a continuous hold loop until the switch is released. This will make the LED stay lit while the switch is pressed.

```
High PORTC.0          ` Light LED DS1

hold
    if PORTA.3 = 0 then hold ` Wait for
                                ` switch to be
                                ` released
endif
endif
```

Once the switch is released, the program continues to the LOW command that turns the LED off. A GOTO command sends the operation back up to the "Main" label, and the whole operation starts again.

```
Low PORTC.0          ` LED DS1 off

goto main             ` Loop back to main
```

MPLAB IDE PROJECT

Now that you have the software, you can try it on your own PICkit 2 Starter Kit (if you have one). First, recreate Listing 1 using a text editor and save it as listing1.bas, or whatever name you want. Now, use the MPLAB IDE to create the software project. The steps to create the project using the Project>Project Wizard menu selection in the MPLAB IDE are listed below.

- 1) *Select a device.* Choose the PIC16F690 MCU, as that is the part included in the PICkit 2 Starter Kit.
- 2) *Select a language tool suite.* Choose the PICBASIC PRO tool suite.
- 3) *Create a new project.* Use the Browse button, and select the directory where you want to store the project and all of the files. I suggest you create it as close to C: as possible, to keep the path name short.
- 4) Add listing1.bas to your project.
WAIT!!!! Don't press the "Next" button, yet. Instead, use a trick that I found — change to the PFILES directory you created and select the P16F690.INC file. Then, click the Add>> button to add it to the project, as well. This will save you an error later. Finally, next to each file, you will see a big "A." Click on that "A" until it changes to a "C."
- 5) At this point you're done, so click the FINISH button.

In my last article, I commented about the error I continued to get because the P16F690.inc could not be found. After much searching and further discussion with the guys from melabs, we finally figured out that I had an older version of MPASMWIN.exe on my PC that was being pulled in. This older version didn't support the newer parts, so it never searched for the P16F690.inc file. Once I removed this older MPASMWIN.exe file, the software found the intended MPASMWIN.exe file and it

compiled without the P16F690.inc specifically included with the project. Therefore, the message after step four may not be necessary for your setup.

PICKIT 2 STARTER KIT/PIC16F690 MCU OPERATION

I mentioned that the RA3 pin needs some special setup steps because of its multiple uses. Two additional steps need to be taken to make this pin work for our purpose. First, the configuration fuses for the PIC16F690 need to have the MCLR feature set to internal operation. That requires you to modify a file that comes with the PICBASIC PRO compiler. The 16F690.inc file contains the PICBASIC PRO default configuration fuse settings. This needs to be modified to have the MCLR_OFF configuration fuse setting set.

The contents of the file should look like the listing which follows when you are done. Declaring the MCLR_OFF fuse makes the RA3 pin a digital input pin and moves the MCLR reset to internal mode. The SW1 switch can no longer reset the MCU, but that's fine since we want it to be a digital input switch. PICBASIC PRO automatically calls the 16F690.inc file in when it compiles your software, so the proper configuration settings will get passed on to the PICkit 2 programmer because of this change.

```

NOLIST
ifdef PM_USED
LIST
include 'M16F6xx.INC'      ; PM header
device pic16f690, intrc_osc_noclkout, wdt_on,
mclr_off
XALL
NOLIST
else
LIST
LIST p = 16F690, r = dec, w = -302
INCLUDE "P16F690.INC"      ; MPASM Header
__config _INTRC_OSC_NOCLKOUT & _WDT_ON &
_MCLR_OFF & _CP_OFF
NOLIST
endif
LIST
```

The PICkit 2 also needs to be disconnected from the RA3 pin after it's done programming, otherwise it will hold the pin high or low — depending upon the setting in the MPLAB IDE. There is an easier way to do this after you hook up the PICkit 2 and enable it, besides actually disconnecting the PICkit 2. We want the PICkit 2 connected because it powers the Low Pin Count board. In the MPLAB Programmer>Settings menu option, you can change the operational setup of the PICkit 2 to run in high-impedance, tri-state mode after successfully programming the PIC16F690 MCU. Figure 3 shows the menu option location.

The window in Figure 4 will appear when you click on the Settings choice. You will see an option to 3-state the programmer. If you don't, then you probably need to upgrade to the latest version of the MPLAB IDE. As I write this, version 8.10 is being released. Click on that option and then click the Apply button.

■ FIGURE 3. Programmer Settings menu.

After completing these steps, you are ready to use the SW1 switch as a digital input. Now, you should be ready to build the project and program it using the PICKit 2 programmer. When the software is compiled and programmed into the PIC16F690, the LED should light only when you press the SW1 switch.

ANALOG INPUT

We've covered how to read a digital input. Now let's see what it takes to read an analog input. In the real world, many things are not digital on or off. Sometimes they have multiple modes. In electronics, we try to make that variable into a changing voltage, so we can measure it with an A/D port. The development board has a potentiometer built in, with the schematic shown in Figure 5.

To read the potentiometer, we just need to measure the voltage at RA0/AN0 with the analog-to-digital converter (ADC) and store the result in a variable. Based upon the variable value, we can light the LEDs. The ADC converts the voltage at the potentiometer into a digital value, based upon the simple equation:

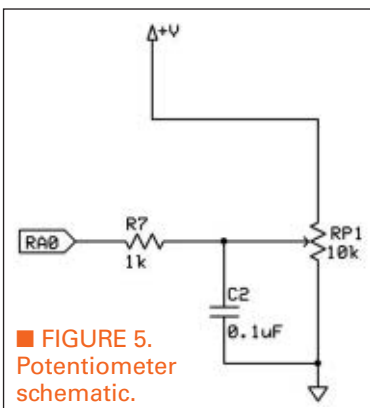
$$\text{ADC Result} = 255(\text{AN0 voltage}/5\text{V})$$

If the potentiometer voltage at RA0/AN0 equals 2.0 volts, then the ADC result equals 102 decimal.

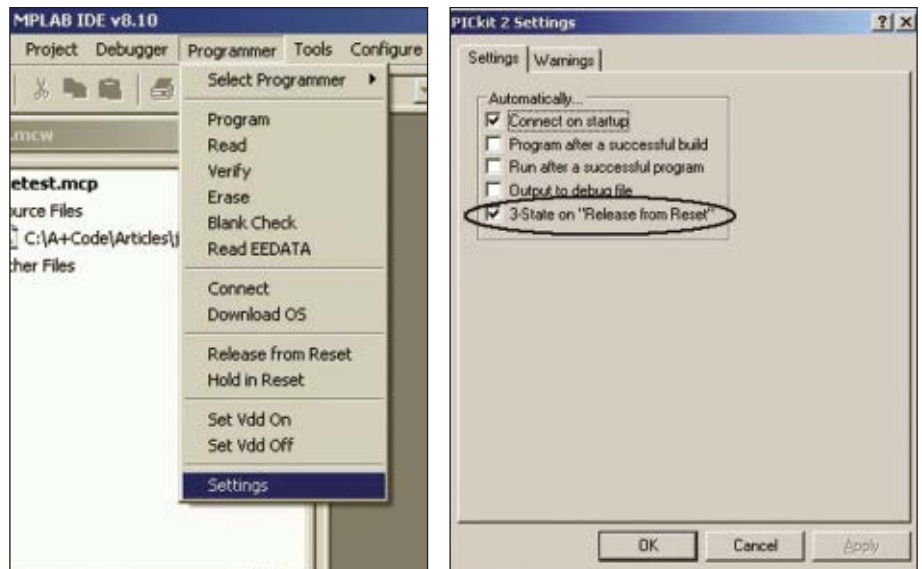
This is what the software in Listing 2 does using the ADCIN command. As you turn the potentiometer to the right, more LEDs will light as the voltage goes up. As you turn it to the left, fewer LEDs light as the voltage decreases. This forms a bar-graph-type display, based upon the position of the potentiometer.

HOW IT WORKS

The heart of the code starts with setting up the ADC. The project only requires eight-bit resolution and a simple clock-source selection for the A/D conversion. A DEFINE statement at the top of the program handles the resolution setup. The clock source requires a little more explanation. We will use the PIC16F690 internal oscillator as the system clock. The internal oscillator _intrc_osc_noclkout option was already selected in that



■ FIGURE 5. Potentiometer schematic.



■ FIGURE 4. PICKit 2 Settings option.

16F690.inc file we modified earlier. When the internal oscillator is selected, the PIC16F690 defaults to 4 MHz on reset (known as the Fosc), and this is divided down by four to create the 1 MHz internal instruction clock. The clock for the ADC has different options to choose from, which determines the speed of the ADC conversion. The Fosc/8 is selected, although any of the choices described in the datasheet will work for this simple example. The second DEFINE statement selects the Fosc/8 selection:

```
Define      ADC_BITS 8      \ Define ADCIN parameters
Define      ADC_CLOCK 1     \ Set number of bits in result
                        \ Set clock source (1=Fosc/8)
```

Variables are needed to store information in the program. A variable for the A/D value and the number of LEDs to light are created as byte variables:

```
adval      var byte        \ Establish variables
bars       var byte        \ Create adval to store result
                        \ Variable to store the number
                        \ of LEDs to light
```

The next section presets all the necessary PIC16F690 internal registers. The ANSEL register controls the ADC pin setup. By setting ANSEL equal to one, only the RA0/AN0 pin is initialized to analog mode. The rest of the ADC pins in the ANSEL register are initialized to zero to put them in digital mode:

```
                        \ Initialize Internal Registers
ANSEL = 1              \ Initialize AN0 to A/D only
```

The internal comparators are shut off by clearing the CM1CON0 and CM2CON0 registers:

```
CM1CON0 = 0            \ Initialize Comparator 1 off
CM2CON0 = 0            \ Initialize Comparator 2 off
```

The TRISA and TRISC registers are set up for their respective operational modes. All of PORTC is set to outputs by clearing the TRISC register. All of PORTA is set

to inputs by setting all the bits in the TRISA register:

```
TRISC = 0           ' PORTC all outputs for LEDs
TRISA = $FF         ' PORTA all inputs for switch
```

The PORTC register is cleared, so all the LEDs are off:

```
PORTC = 0           ' Preset LEDs off
```

The main loop starts with the Main label. The ADCIN command is used to measure the voltage at the RA0/AN0 pin and store the eight-bit result in the variable "adval":

```
Main
'*** Read A/D value *****
ADCIN 0, adval      ' Read channel 0 to adval
```

The value measured is then shifted to the right six bits, using the shift right math operator in PICBASIC PRO. After shifting, the two most significant bits (MSB) remain — giving a result of 0, 1, 2, or 3 that is stored in the variable "bars." For example, if the RA0 voltage is 2.0 volts, the ADC measurement is 102, as calculated earlier. The binary value is %01100110. Shift that result to the right six bits and the result is %00000001, because zeros replace the shifted bits:

```
'*** Drive LEDs *****
bars = (adval >> 6) ' Shift for 2 MSB for values 0
                  ' to 3
```

The value of bars is then used as an index to select a value to send to the PORTC register using the LOOKUP command. Each selection lights a different number of LEDs that matches the value of bars plus one:

```
if switchstate = 1 then      'Test for LED direction
lookup bars,[1,3,7,15], PORTC 'Drive LEDs to Right
```

LISTING 2: A/D example.

```
' Define ADCIN parameters
Define ADC_BITS 8      ' Set number of bits in result
Define ADC_CLOCK 1     ' Set clock source (1=Fosc/8)

' Establish variables
adval var byte         ' Create adval to store result
bars var byte          ' bars has number of LEDs to light

' Initialize Internal Registers

ANSEL = 1              ' Initialize AN0 to A/D only
CM1CON0 = 0            ' Initialize Comparator 1 off
CM2CON0 = 0            ' Initialize Comparator 2 off
TRISC = 0              ' PORTC all outputs for LEDs
TRISA = $FF            ' PORTA all inputs for switch
PORTC = 0              ' Preset LEDs off

'*** Main Program Loop ***

Main
'*** Read A/D value *****
ADCIN 0, adval         ' Read channel 0 to adval

'*** Drive LEDs *****
bars = (adval >> 6) ' Shift for 2 MSB for values 0 to 3
lookup bars, [1,3,7,15], PORTC ' Drive LEDs to Right

goto main              ' Loop back for new A/D sample
```

The LEDs will light immediately, because the LOOKUP command is placing the value directly into the PORTC register, so that value is displayed at the PORTC pins or LEDs. Finally, the program loops back to the Main label using a GOTO command to start the process all over again:

```
goto main              'Loop back for new A/D sample
```

Create the Listing2.bas file and save it. Then, follow the same steps to create the MPLAB project for this example. You don't need to do anything special this time for the configuration or PICkit 2. You can build it, and then program the part. Hopefully, you are successful and at least one LED is lit. As you turn the potentiometer, the number of LEDs lit should change.

CONCLUSION

That whole RA3 setup with the configuration fuses and the PICkit 2 tri-state mode can be confusing to the beginner, since a lot of this requires you to read through several sections of the datasheet — which is hundreds of pages long. It's really required reading, though, to completely understand the device you are using. The nice thing is, once you understand the PIC16F690, many other MCUs operate similarly or exactly the same.

You could add a switch to the PICkit 2 Starter Kit development board and connect it to a different port pin. In fact, one of the other PICkit 2 boards you can get is the 28-pin board for larger parts. It has the switch wired to a different pin, so it is a little easier to create software to read a switch.

When you complete these projects, you've accomplished a difficult task for someone who is just getting started. You also have a great block of code to reuse in future applications. Modifying the configuration fuses and changing the

programmer setup are not your typical entry-level steps, but they can surely confuse you if you tried all this without any support or explanation. I don't know how many times I tried something I thought was simple, only to find out some piece of information I needed was hidden in a document. Many times, it was my own fault because I chose not to read the datasheet and assumed I knew what to do. Remember, when you are starting out and think you just don't get it, you probably do understand but just missed one or two simple steps. That is what keeps me writing my books and articles like this, which are dedicated primarily to the entry-level programmer. Forums are another great source of help, and Microchip has a forum with lots of information including PICkit 2 help at <http://forum.microchip.com>. Speaking of PICkit 2, there is a new version of software you can download that adds some great features (which I plan to explain more about in a future article). That programmer/debugger just gets better and better. If you have problems with this project, you can email me at chuck@elproducts.com. My new book *Beginner's Guide to Embedded C Programming* should be available by July, for those getting started with the C language. It also uses the PICkit 2 Starter Kit so, if you have one of those, you are halfway there. See you in the September issue of *Nuts & Volts*. **NV**

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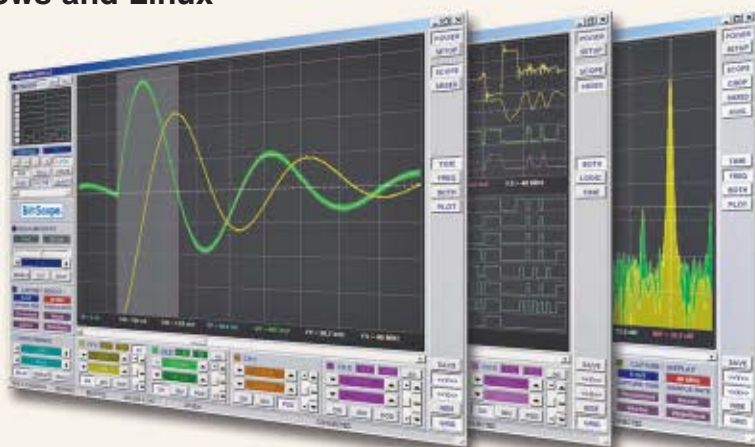
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■ BY FRED EADY

A DISCERNING TOUCH

I HAD THE PLEASURE OF taking last month's Xilinx/Microchip capacitive touch sensing prototype hardware on the road to Abel Elementary School in Sarasota, FL. The occasion was Space Day, which is an annual space-science event sponsored by the Lockheed Martin Corporation. Over 150 fourth and fifth grade fingers touched the tin touch sensor, which was insulated by and tied down to a desk with a piece of cellophane tape I scarfed from a teacher's desk. Thanks to a CleverScope and my Lenovo laptop, each of the Space Day fourth and fifth graders also got to watch the relaxation oscillator waveforms change in frequency as their fingers mingled with the touch plate's capacitance.

Lockheed Martin throws Space Days all over the United States in communities the company does business in. The idea behind Space Day is to develop students' interest in math, science, and technology. From what I saw, we have a good crop of scientists, engineers, and astronauts coming along in Sarasota.

Last time, we took a look at the basic hardware and firmware required to implement a capacitive touch system. In doing so, we fashioned a relaxation oscillator out of a couple of PIC microcontroller comparators and a Xilinx CPLD set up as an SR Latch. This month, I'm going to show you how to put together a capacitive touch system using a single PIC microcontroller.

PIC16F727 FLYOVER

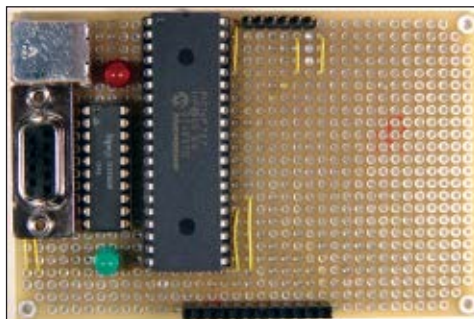
On the outside, the PIC16F727 looks just like any other 40-pin PIC microcontroller. If you compare the PIC18F4620 pinout to the PIC16F727 pinout, you will find them functionally identical. The PIC16F727 pinout is also identical to the functional physical pinout of the PIC16F877. In that the PIC16F727 and PIC16F877 are 16F parts, it

stands to reason that the PIC18F4620 has an advantage in terms of the amount of program Flash and SRAM. However, there are some differences within the PIC16F727 worth pointing out as these differences directly affect our PIC16F727 design methodology.

The PIC16F727's I/O subsystem is multiplexed just as it is on the PIC18F4620 and PIC16F877. Note that the PIC16F727 places a multiplexed VCAP function at pins 2, 7, and 14. A ceramic capacitor in the range of 0.1 μF to 1.0 μF must be attached to the VCAP pin of your choice when the PIC16F727 is powered by +5 VDC. The ceramic capacitor on the selected VCAP pin acts as a bypass capacitor for the PIC16F727's internal LDO (low drop out) voltage regulator. Due to the PIC16F727's internal design, the maximum supply voltage that can be applied to the PIC16F727's internal electronics is 3.6 VDC. The PIC16F727 LDO allows the PIC16F727 I/O to operate in standard +5 VDC systems while maintaining a safe operating voltage for the PIC16F727 internal logic. If the PIC16F727 design is powered by a supply voltage equal to or below 3.6 VDC and no +5 VDC I/O interaction is required, the

services of a PIC16F727 can be employed. The PIC16F727 does not contain an internal LDO and as a consequence doesn't require an external LDO bypass capacitor. You can also use a PIC16F727 with a 3.6 VDC power supply and disable the PIC16F727's internal LDO. Disabling the PIC16F727's VCAP pins will reduce the PIC16F727's operating current by 300 μA .

■ **PHOTO 1.** We are going to reuse some touch code from last time in this project. The PIC16F727 touch hardware is also reusable as you can push a similar pinned PIC into the 40-pin socket and use the circuit for projects that don't utilize capacitive touch sensing. In fact, you can simply turn off the PIC16F727's capacitive sensing module and run the PIC16F727 like an everyday PIC.

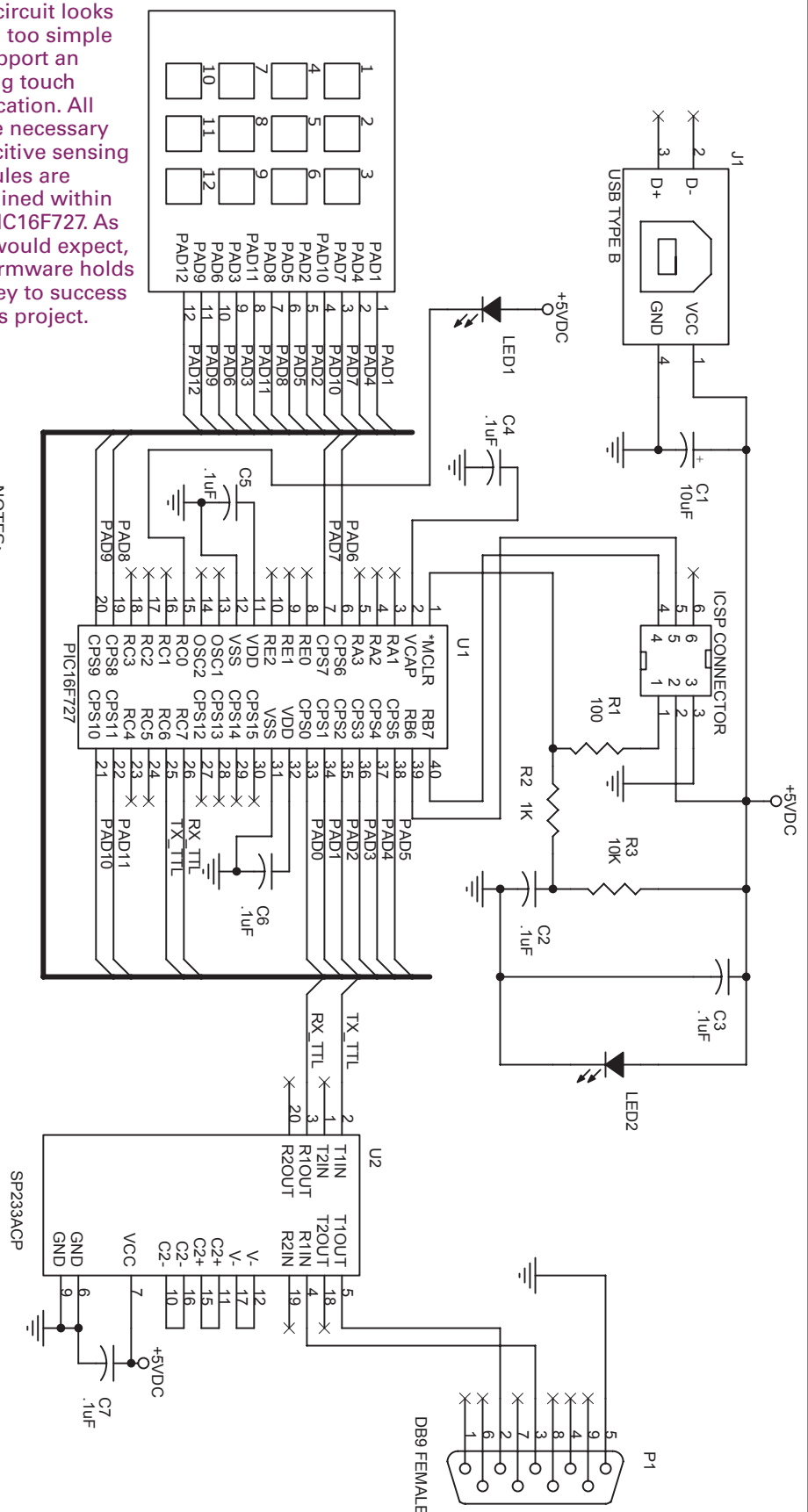


The internal clocks are getting better with each spin of PIC hardware. In most pre-PIC16F727 microcontrollers, you'll find that the maximum operating frequency of the system clock is directly proportional to the power supply voltage. Usually, the higher the power supply voltage, the higher the maximum system clock frequency. Not so with the PIC16F727. Both the PIC16F727 and the PIC16LF727 clock at the same rate at the same power supply voltage levels. The PIC16F727's logic can be driven at a multitude of frequencies by its internal 500 kHz clock. A 32X PLL can be activated to pump the PIC16F727's precision 500 kHz clock signal up to 16 MHz. A CPU clock postscaler allows the PIC16F727 to clock its internal logic at a rate as low as 62.5 kHz without the PLL and 2 MHz when the 32X PLL is activated. Standard PIC external clocking can also be used. The PIC16F727 can accept a maximum external clock source of 20 MHz. However, the 32X PLL is not available in the clocking loop when the external clock is selected.

The new PIC16F727 also incorporates a feature that I really like. The PIC16F727's Timer1 count can be programmatically gated or physically gated via an I/O pin. Recall that we used Timer0 and some PIC timing firmware as the Timer1 gate in our prototype capacitive touch hardware. The PIC16F727 will allow us to use Timer0 overflows and minimal interrupt handler code to automatically gate the relaxation oscillator count to Timer1.

If you take yet another look at the PIC16F727 datasheet, you'll notice that some of the PIC16F727 I/O pins are multiplexed with CPSxx functionality. CPS is short for Cap Sensor. The PIC16F727's CPSxx pins are part of the PIC16F727's internal capacitive sensing module. The PIC16F727's capacitive sensing module is made up of a

■ **SCHEMATIC 1.** This circuit looks much too simple to support an analog touch application. All of the necessary capacitive sensing modules are contained within the PIC16F727. As one would expect, the firmware holds the key to success of this project.



■ **PHOTO 2.** As the touch sensing engineers, we are required to know what's really behind the touch keypad from a hardware point of view. The idea is to cover this keypad with a flashy graphic design and some Plexiglas.

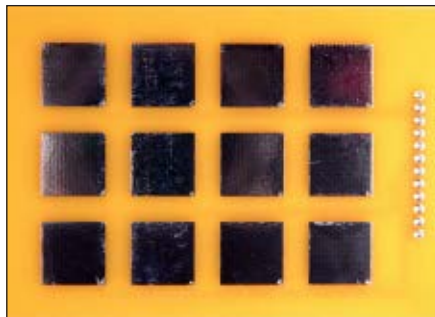
16-input multiplexer and a capacitive sensing oscillator, which interact with the PIC16F727's timers. Using the PIC16F727 as our base microcontroller, all we have to do is add some touch pads and the basics presented in Tom Perme's mTouch-inspired firmware to implement a capacitive sensing application. With that, let's build up a capacitive sensing system based solely on the PIC16F727.

CAPACITIVE SENSING HARDWARE DESIGN

All of the details of our capacitive sensing system hardware can be gleaned from Schematic 1. To keep the parts count low, we will get our power from a standard USB portal. A USB type B connector and an active USB port on a laptop or desktop computer are all we need to import +5 VDC into our capacitive sensing design.

Our system is simple enough to be assembled on a piece of perfboard using point-to-point wiring techniques. I chose to use a custom-designed plated-through hole perfboard, which allows me to mount SMT passive components on either side of it. I have supplied the perfboard ExpressPCB file as a download from the *Nuts & Volts* website (www.nutsvolts.com) for those of you that wish to assemble your own capacitive sensing system in this manner. To avoid the pleasure of drilling special holes in the perfboard, I've mounted the six-pin RJ-12 ICSP connector on a separate printed circuit board (PCB). I've included the ExpressPCB layout file for the ICSP board for you in the download package, as well.

As you can see in Photo 1, our capacitive sensing system hardware consists of the PIC16F727, a type B USB receptacle, a nine-pin female shell connector, an ICSP programming/debugging portal, an SP233ACP RS-232 interface IC, and a keypad interface. I placed the VCAP filter capacitor on RA0 to avoid wasting one of the CPS inputs. I added an LED for debugging purposes. The debugging LED can also be used to indicate a "touch" on the keypad. The idea behind the RS-232 port is to provide a way to show which keypad button is under the influence of a finger. I was originally going to fabricate a touch keypad using square pieces of tin soldered to a perfboard backing. After pricking my finger multiple times on the first raw cut prototype tin touch pad (I deburred the Space Day touch pad), I decided to bite the bullet and put the touch pads down on a PCB. I used the Microchip touch pad guidelines laid out in application note AN1102 to put the tinned copper pads on a piece of fiberglass, as you see them in Photo 2. Everything is attached to the



PIC16F727 perfboard in Photo 3. Let's use the HI-TECH PICC C compiler to put some mortar between these bricks.

MATCHING FIRMWARE TO FUNCTION

The flow of the firmware follows the functionality of the hardware. A very important piece of hardware is the keypad. As you can see in Schematic 1, there are a total of 16 CPS inputs. Our keypad has only 12 touch pads. So, let's define each physical touch pad in our CPS firmware:

```
//*****
//      KEYPAD BIT STRUCTURE
//*****
typedef struct
{
    char PAD0 : 1;
    char PAD1 : 1;
    char PAD2 : 1;
    char PAD3 : 1;
    char PAD4 : 1;
    char PAD5 : 1;
    char PAD6 : 1;
    char PAD7 : 1;
    char PAD8 : 1;
    char PAD9 : 1;
    char PAD10 : 1;
    char PAD11 : 1;
} PPad;

PPad keypad;
//*****
//      SENSOR COUNT DEFINITIONS
//*****
#define      MAXSENSORS      12
```

The typedef defines a structure called PPad. The statement PPad keypad; forms a structure called keypad of type PPad, which contains a bit that references each of the 12 keypad touch sensors. The MAXSENSORS definition is used to scale the array sizes and firmware loop counts to the number of keypad touch sensors that we will use in the application. For instance, if we were to implement a standard 10-key numeric keypad (0-9), we would set MAXSENSORS to 10 and ignore the keypad sensors to the left and right of the bottom-most zero keypad sensor. We don't have to make any changes to the PPad bits as we simply won't reference the unused PPad bits in our 10-key application. The bits within the keypad structure are manipulated in this manner:

```
keypad.PAD0 = 1; //sets PAD0 bit to 1
keypad.PAD0 = 0; //sets PAD0 bit to 0
```

As you've probably already ascertained, we'll use the bits of the keypad structure to denote the status (pressed or idle) of each keypad sensor.

The first piece of hardware that each keypad touch sensor encounters within the PIC16F727 is the CPS multiplexer. When the capacitive sensing module is activated, the CPSCON1 register contains the bits that determine which

one of the CPS multiplexer channels is active. Our firmware will manipulate the CPSCON1 bits in such a way as to scan the keypad sensors. Here's the function that will utilize the CPSCON1 register and its multiplexer channel selection bits:

```

/*****
/**  SELECT NEXT CPS CHANNEL
*****/
void select_next_sensor(void)
{
    ++sensor_index;
    if(sensor_index >= MAXSENSORS)
    {
        sensor_index = 0;
    }
    CPSCON1 = sensor_index;
}

```

The `select_next_sensor` code demonstrates how the `MAXSENSORS` value is put into play. The `CPSCON1` register will cycle from zero up to `MAXSENSORS - 1` resulting in the active CPS multiplexer channels of 0 to 11. The four least significant bits of the `CPSCON1` register select the multiplexer channel.

Before we can use the CPS multiplexer, we must activate the capacitive sensing module. This is done by setting the most significant bit of the `CPSCON0` register. We can also set the current consumption of the capacitive sensing oscillator with `CPSCON0` bits <2:3>:

```

/*****
/**  SETUP CAP SENSE MODULE
*****/
CPSCON0 = 0b10001100;
CPSCON1 = 0;

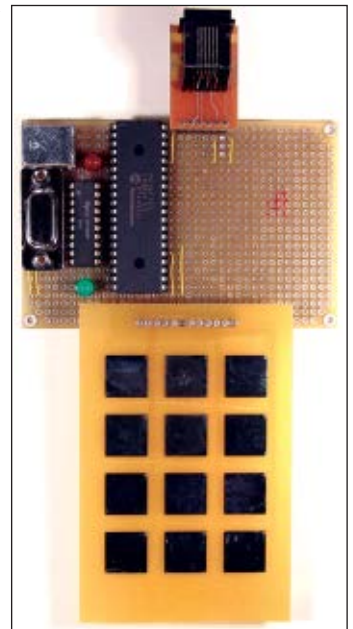
```

The `CPSCON0` and `CPSCON1` code I just presented is part of the PIC16F727 initialization function. Within the `CPSCONx` code, the capacitive sensing module has been activated, the capacitive sensing oscillator current is at its highest level, and the first multiplexer channel to be selected will be channel 0.

The capacitive sensing oscillator is made up of a constant current source and a constant current sink. As oscillators go, that says triangle waveform to me. While in the throes of designing our touch system prototype, we used the CleverScope to see the sourcing and sinking of our comparator-based relaxation oscillator as a triangle waveform. To get the sink or source status of the capacitive sensing oscillator, we can query the `CPSOUT` bit, which indicates sourcing when set and sinking when clear.

Just like our prototype Xilinx CPLD/PIC comparator-based capacitive sensing oscillator, the PIC16F727 oscillator is designed to drive a single touch pad capacitive load and deliver ticks to `Timer0` or `Timer1`. We can set three differing capacitive sensing oscillator current levels, which allow a maximization of the number of counts for a fixed time base. The capacitive sensing oscillator current level setting also maximizes the timer count differential for a given change in frequency. Recall that the whole idea behind capacitive sensing is to create a logically noticeable change in the capacitive sensing oscillator frequency when the touch sensor load capacitance changes. We see this change in our firmware as timer ticks with the tick count (oscillator frequency) going

■ **PHOTO 3.** Here's what my capacitive sensing rig looks like when all of the pieces are connected.



down when the touch sensor is being accessed. In addition to activating the capacitive sensing module and its capacitive sensing oscillator, we must condition the CPS I/O pins to interface with the touch sensors. That means that all of the CPS I/O pins that are interfacing to the keypad sensor array have to be set for analog operation. This is easily done by setting the corresponding bits in the `ANSEL` (Analog Select) and `TRIS` registers:

```

/*****
/**  SETUP I/O PORTS
*****/
TRISA = 0b10111111;    //PARTIALLY AVAILABLE
TRISB = 0b11111111;    //CPS USED
TRISC = 0b11111110;    //PARTIALLY AVAILABLE
TRISD = 0b11111111;    //CPS PARTIALLY USED
TRISE = 0b11111111;    //AVAILABLE

ANSELB = 0b00111111;   //PORTB = ANALOG
ANSELD = 0b11111111;   //PORTD = ANALOG
ANSELE = 0;            //PORTE = DIGITAL

```

Note that I assigned all of the `PORTD` pins as CPS inputs. In reality, you can use the most significant pins of `PORTD` for standard I/O operations as we aren't using them for CPS purposes in this application. If you choose to use the unused `PORTD` I/O pins, be sure to clear the associated bits in the `ANSELD` register and set the `TRISD` register bits accordingly.

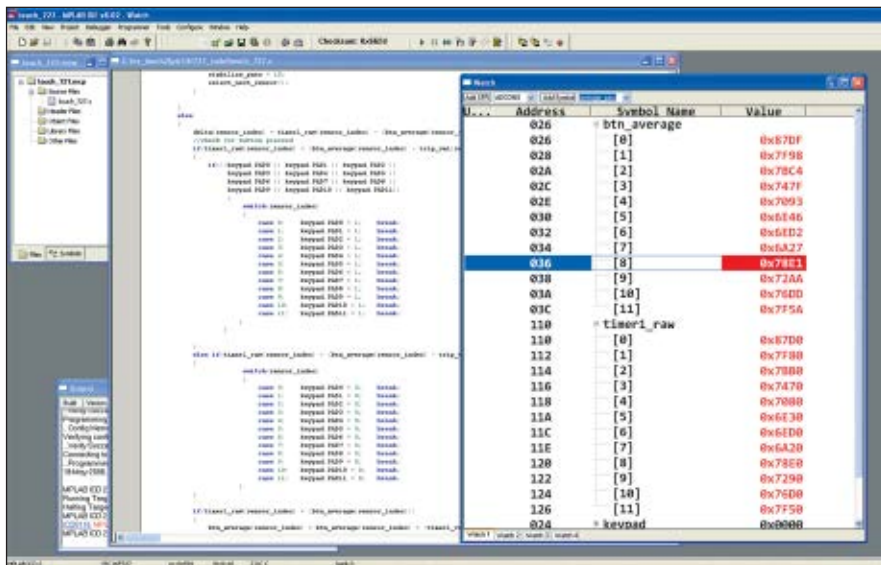
`Timer1` has the option of being programmatically gated. So, to reduce our coding complexity and save some code at the same time, our firmware design will have the capacitive sensing oscillator driving counts into `Timer1`. The frequency count we ultimately retrieve from `Timer1` must be based on a predictable slice of time (a time base). Thus, we will gate the frequency counts to `Timer1` with every overflow of free-running `Timer0`. This arrangement positions the `Timer0` overflows as our time base. Let's look at the timer code that makes this happen:

```

/*****
/**  SETUP TIMERS
*****/
OPTION = 0b11000101;    //Timer0 CLK ON FOSC/4
T1CON = 0b01000101;
T1GCON = 0b11100001;

```

The most significant bit of the `OPTION` register is set indicating that `PORTB` pull-ups are disabled. From most significant bit to least significant bit, the next bit of impor-



■ **SCREENSHOT 1.** This is a snapshot of my keypad sensor values after a few seconds of idle operation.

selection in the T1GCON register. The most significant bit of this register is set telling us that Timer1 counting is under the control of the Timer1 gate feature. Bit 6 of the T1GCON register determines the gate polarity. In our case, bit 6 is set and that means that the gate signal is active when it is logically high. Timer1 Gate Toggle Mode is selected as bit 5 of T1GCON is set. Enabling Timer1 Gate Toggle Mode allows us to measure a full cycle during a gate cycle. In Single Pulse Mode, the measurement cycle begins on the rising of the gate signal and ends on the first falling edge of the gate signal.

tance to us in the OPTION register is bit 5, which is cleared. The logical state of bit 5 in the OPTION register selects the internal instruction clock (FOSC/4) as the Timer0 clock source. If you check the PIC16F727 configuration fuse settings in the complete firmware listing I have provided in the download package, you will see that I have enabled the 32X PLL and we are running on the internal 500 kHz core clock with no postscaling. That puts our FOSC frequency at 16 MHz. Moving to the next significant bit of the OPTION register, we clear bit 3 to assign the prescaler to the Timer0 module. The three least significant bits of the OPTION register set the Timer0 prescaler value, which is 1:64. We want to select the Timer0 prescaler value so that we get enough counts into Timer1 to see a significant change in the frequency count and at the same time not allow Timer1 to overflow during a measurement cycle.

Now that you know what's feeding Timer1, let's analyze T1CON most significant bit to least significant bit. T1CON's most significant pair of bits determines the Timer1 clock source, which, in this case, is the system clock (FOSC). If we've done our homework, we should not have to prescale the input of Timer1. So, we clear the Timer1 prescaler bits 5 and 4. Timer1 can also act as an independent dedicated oscillator. That's not in our design and we'll disable the dedicated oscillator feature by clearing bit 3. In addition, we're not interested in synchronizing an external clock input with the system clock and we indicate that by setting bit 2 of the T1CON register. The least significant byte of T1CON is the Timer1 switch. Setting bit 0 enables Timer1.

The frequency counting magic is performed by our bit

ment on the rising edge of the gate signal and instead of ending the measurement on the falling edge of the gate signal, the measurement is terminated on the next rising edge of the gate signal. In our design, the low-to-high gate signal is supplied by a Timer0 overflow. We know where the gate signal originates because we have cleared bit 1 and set bit 0 of the T1GCON register, which selects Timer0 overflow as the Timer1 gate signal generator. The Timer1 gate functionality is null and void when Timer1 is disabled.

To collect our frequency counts from the Timer1 registers, we really need to know when a gate event has completed. The easy way to keep up with that would be to trap on a gate-related interrupt if one existed. It does:

```

//*****
//*   SETUP INTERRUPTS
//*****
TMR1GIF = 0;      //clear the interrupt flag
TMR1GIE = 1;      //enable gate interrupt
enable_GLOBALint; //enable all interrupts

```

Enabling the Timer1 Gate Event Interrupt paves the way for us to gather the frequency information we require from the Timer1 registers by invoking a gate event interrupt handler. There's no need to post the interrupt handler code here as you already know how it works. The capacitive sensing interrupt handler for the PIC16F727 is identical in function to the prototype touch sensor interrupt handler we wrote about in the previous installment of Design Cycle.

There's no harm in reviewing the process for those of you that may not have had the opportunity to read last month's words. So, let's flow through the Gate Event Interrupt handler code:

```

//*****
//*   SENSOR COUNT DEFINITIONS
//*****
#define MAXSENSORS      12
#define NUM_AVG_PASSES  3
#define NUM_STAB_PASSES 5

```

SOURCES

PIC16F727 from Microchip (www.microchip.com)

SP233ACP from Exar/Sipex (www.exar.com)

HI-TECH PICC C Compiler from
HI-TECH Software (www.htsoft.com)


```

//*****
//* TOUCH INTERRUPT HANDLER
//*****
void interrupt SENSORS(void)
{
    if(TMR1GIF && TMR1GIE){
        TMR1GIF = 0;
        Timer1OFF;

        timer1_val[sensor_index] = make16(TMR1H,TMR1L);
        timer1_raw[sensor_index] <= 4;

        // Stabilize the btn_average value
        if(stabilize_pass > 0) {
            --stabilize_pass;
            btn_average[sensor_index] =
                timer1_raw[sensor_index];
            reset_timer1();

            if((stabilize_pass == 0) &&
                (sensor_index < (MAXSENSORS - 1))) {
                stabilize_pass = 10;
                select_next_sensor();
            }
        }
    }

    This code is invoked every time a Timer1 gate event
    completes. Each touch sensor frequency value is captured
    and stored in an array memory cell. Every three measure-
    ment cycles, the frequency values for each sensor are
    averaged and are also stored away in an array memory
    cell that is unique to each sensor. In order to begin with a
    good unloaded (no finger on the sensor) frequency value,
    we must accumulate enough frequency measurements to
    establish an initial average frequency for each keypad sen-
    sor. We do this by making five stabilization measurement
    passes. You can see my keypad sensor average and raw
    values following stabilization in Screenshot 1. Note that
    the average and raw values are very close to the center of
    the 16-bit Timer1 range. Being near the center of the
    count allows us plenty of headroom to swing low when a
    key is pressed with no fear of overflow when the key is
    idle. Once the keypad sensor values are stable, we can
    begin our loops looking for fingers in the sensor fields:

    else
    {
        //check for button pressed
        if(timer1_raw[sensor_index] < (btn_average[sensor_index]
            - trip_val[sensor_index])) {
            if(!(keypad.PAD0 || keypad.PAD1 || keypad.PAD2 ||
                keypad.PAD3 || keypad.PAD4 || keypad.PAD5 ||
                keypad.PAD6 || keypad.PAD7 || keypad.PAD8 ||
                keypad.PAD9 || keypad.PAD10 || keypad.PAD11)) {
                switch(sensor_index) {
                    case 0: keypad.PAD0 = 1; break;
                    case 1: keypad.PAD1 = 1; break;
                    case 2: keypad.PAD2 = 1; break;
                    case 3: keypad.PAD3 = 1; break;
                    case 4: keypad.PAD4 = 1; break;
                    case 5: keypad.PAD5 = 1; break;
                    case 6: keypad.PAD6 = 1; break;
                    case 7: keypad.PAD7 = 1; break;
                    case 8: keypad.PAD8 = 1; break;
                    case 9: keypad.PAD9 = 1; break;
                    case 10: keypad.PAD10 = 1; break;
                    case 11: keypad.PAD11 = 1; break;
                }
            }
        }
    }
}

```

A finger over a keypad sensor will reduce the frequency count. We pick that up with the code you see that follows the comment `//check for button pressed`. Note that we put the keypad structure elements to work by setting the respective sensor keypad.PADx bit when a finger is detected above the sensor. Conversely, we clear the sensor keypad.PADx bit when there is no finger capacitance mixing with the keypad sensor capacitance:

```

else if(timer1_raw[sensor_index] >
    (btn_average[sensor_index] -
        trip_val[sensor_index])+30) {

    switch(sensor_index)
    {
        case 0: keypad.PAD0 = 0; break;
        case 1: keypad.PAD1 = 0; break;
        case 2: keypad.PAD2 = 0; break;
        case 3: keypad.PAD3 = 0; break;
        case 4: keypad.PAD4 = 0; break;
        case 5: keypad.PAD5 = 0; break;
        case 6: keypad.PAD6 = 0; break;
        case 7: keypad.PAD7 = 0; break;
        case 8: keypad.PAD8 = 0; break;
        case 9: keypad.PAD9 = 0; break;
        case 10: keypad.PAD10 = 0; break;
        case 11: keypad.PAD11 = 0; break;
    }
}

```

The value of 30 you see added on at the end of the else if statement is a hysteresis value. We want to be sure that the keypad sensor is really idle before marking it as not pressed. We repeat the finger check process three times for each of the 12 keypad sensors. Before we move to the next sensor, we compute the current sensor's average frequency count and store it away in the btn_average array. The next sensor is then selected and Timer1 is reset in preparation for the next sensor's measurement cycle:

```

//compute average
if(--average_pass == 0) {
    btn_average[sensor_index] +=
        (timer1_val[sensor_index] -
            (btn_average[sensor_index] / 16));

    average_pass = NUM_AVG_PASSES;
    select_next_sensor();
}
reset_timer1();

```

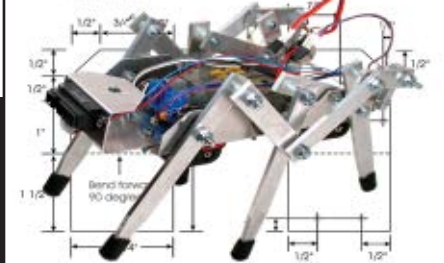
Piece of cake.

THE MAGIC TOUCH

Yep. That's what you have now. However, you're in on the "magic." Capacitive touch sensing is now a part of your Design Cycle. So, build up your own version of the capacitive sensing hardware I've described here. Then, set up your personal computer's terminal emulator for 56 kbps and connect it to the PIC16F727's RS-232 port. When you pass your finger over a keypad sensor, you should see a positive response to your "touch" within the terminal emulator window. **NV**

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ROBOTICS

PERSONAL

UNDERSTANDING, DESIGNING & CONSTRUCTING ROBOTS & ROBOTIC SYSTEMS

■ BY VERN GRANER

POWER FLOWERS

Last month, I presented the workbenches of the rich (or not) and famous (or not) and recounted their tips, tricks, and general advice for creating a suitable hobbyist workbench. I also introduced the *Workbench Design Challenge* contest with some really great prizes contributed by Parallax. In case you missed it, check the Workbench Design Challenge details and official contest rules on the *Nuts & Volts* web forum (see Resources)

As I am still in the process of summarizing the great feedback I received from folks about the Habitat article, I'm not quite ready to publish Habitat for Hobbies Part 2. Instead, I've decided to take a different approach this month and present a simple robotic project that should be within the grasp of most electronic hobbyists. The idea is to create some neat moving effects using a single servo motor and something many of us have lurking in a cabinet in the kitchen.

ORGANIC ROBOTICS?

One evening after dinner at "Casa Graner," I was sketching some designs in a notebook while my wife Kym was bustling around the kitchen.

I was bouncing some ideas off of her when she mentioned that most of the things I had been designing were very industrial-looking. She encouraged me to try and find something more organic to create or simulate. As I continued to sketch up some ideas for animatronic sculptures, she reached into the dishwasher and retrieved a vegetable steamer. As she flipped it from open to shut while preparing to put it away, inspiration struck. I asked her if I could borrow the steamer for a moment and I went upstairs to my workbench. It took about an hour, but when I was done I had cut a servo-sized hole in the bottom of the thing, added a servo, and some rudimentary connecting rods to the "petals" of the steamer. The Power Flower was born!



POWER FLOWER — ACTIVATE!

I brought the device downstairs and showed my wife how I could cause the flower to open and close in a very familiar organic way just by moving one servo. The thing really did look like a metal flower opening its petals to the sun. My wife was very impressed with the result and then, noticing the large servo-sized hole in the steamer, told me to hold on a second while she wrote "pick up four vegetable steamers" on the shopping list. Oops.

As I discovered, the Power

■ FIGURE 1. EFX-TEK Prop-1 microcontroller board.

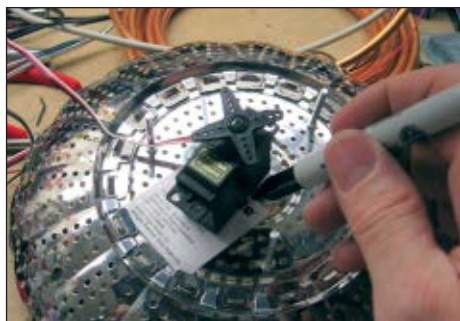


■ FIGURE 2. Vegetable steamer.



■ FIGURE 3. Open the steamer on your workbench.

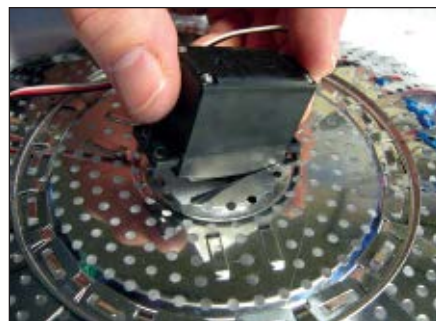




■ FIGURE 4. Center the servo motor horn and draw an outline around the servo.



■ FIGURE 5. Cut along the lines.



■ FIGURE 6. Test to make sure the servo fits properly.

Flower is surprisingly simple to make but, when completed, looks very complex and exciting. By mixing in a microcontroller and a few simple sensors, you can make your Power Flower react to light or sound. Add a few LEDs and you can have it blink or fade colorful lights. The resulting project is relatively inexpensive (costing on the order of less than \$20 per flower, depending on what you have laying about), yet can be made active and even interactive with just a little bit of effort. Better yet, all the software to get started is available from the *Nuts & Volts* website (www.nutsvolts.com) with this article. The software will allow you to make your flower (or flowers) move using an inexpensive EFX-TEK Prop-1 controller (Figure 1) and will help you get started controlling your very own garden of Power Flowers! All we have to do is gather a few parts and get to building.

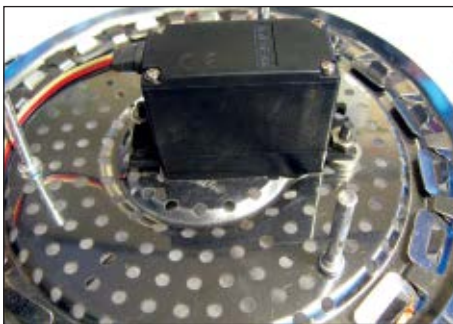
THE PARTS

We'll begin with the basic parts you will need to create the flower (an itemized list of the parts, sources, and part numbers are located in the sidebar). First, you'll need a vegetable steamer such as the

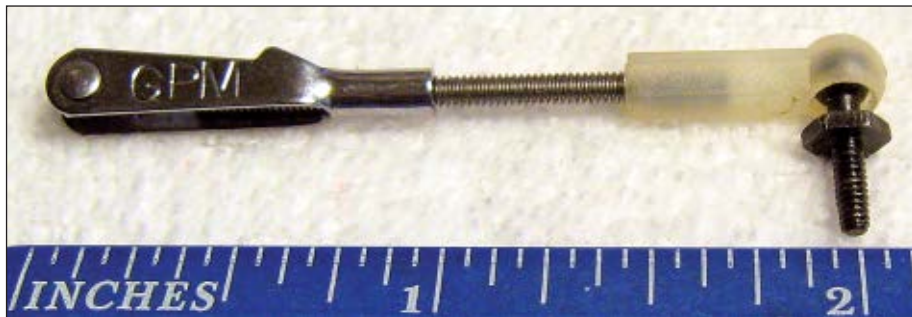
one shown in Figure 2. I have found these steamers in the kitchen utensil aisles of the grocery store. They are usually available in multiple sizes. I suggest you use a smaller 6" sized one for your first version of the flower as there are fewer "petals" to push around so your servo strength will not be as important.

Next, you will need a servo motor. Most any servo you have handy will do. In my first flower, I used the Futaba 3003, but in later flowers I used the Parallax Servo that comes bundled with the "what's a microcontroller" kit. You will need the quad-point horn in order to attach the four push-rods to the petals. Though the first prototype of

■ FIGURE 7. Drill holes and use screws to mount the servo to the back side of the steamer.



■ FIGURE 9. Cut approximately 1.75" of 2-56 threaded rod and attach the clevis and ball links.



the flower I created used some stiff piano wire as push rods, I found that a model airplane steel clevis, a bit of 2-56 threaded rod, and some ball links worked much better. The ones I used are shown in Figure 8.

PREPARING THE "PETALS"

The steamers, when new, tend to be somewhat stiff to operate. In fact, a brand new steamer will sometimes require more torque to open and close than a relatively low-torque servo can provide. The solution is to either 1) reduce the friction of the steamer, or 2) buy a higher torque

■ FIGURE 8. Model airplane clevis and ball links.



■ FIGURE 10. Attach the ball link to the servo horn.





■ FIGURE 11. Solder one of the washers (included in the ball links package) into the slot of a small machine screw.



■ FIGURE 12. Insert the washer/screw combo into one of the holes on a petal (as shown) and tighten a nut on the outside of the petal.



■ FIGURE 13. Attach the clevis to the washer/screw combo to anchor the rod to the petal.

servo. I chose to simply reduce the friction of the steamer. To do this, I went around the edge of the steamer base and slightly loosened each of the metal tabs that hold the petal to the center. Next, I would slightly bend each of the petals so they wouldn't rub against each other quite so hard. Lastly, I added a dab of light machine oil to each of the metal tabs that held each petal to allow them to move more easily. When you are done tweaking, you should be able to flop the steamer from open to fully closed without it binding in any position. This can be tricky and might take a bit of patience, but once you have it, the petals should open and close with just gravity as you flip the steamer from upright to inverted. Once you've prepared the steamer, it's time to start construction.

ASSEMBLY

To make your first flower, start by opening the steamer on your

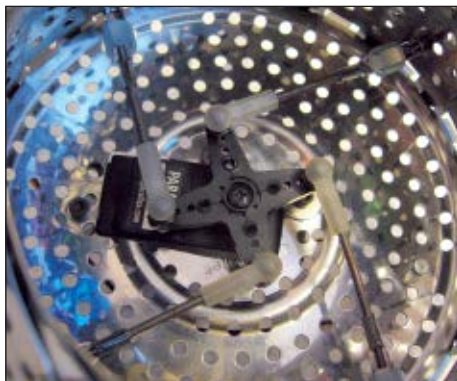
■ FIGURE 14. Attach the other three rods in this manner.



workbench (Figure 3). Place the servo motor so that the motor shaft is as close to center as you can make it, then trace the outline of the motor on the metal using an indelible marker (Figure 4). Once you have the tracing, use a tool with a cutting blade to cut the rectangle of metal from the center of the steamer (Figure 5). Note: Remember to wear ear protection as doing this tends to be rather loud!

Once you have the hole in the steamer, test fit the servo and make sure it drops into place (Figure 6). Once you have it in place, mark the four mounting holes, then drill at least two holes to mount the servo (Figure 7). You may be able to get away with only two screws to hold the servo in place as not much torque is present on the servo when it is in operation. In most cases, you should mount the servo from the bottom of the steamer so that the

■ FIGURE 15. Move the servo through its length of travel, then insert the center screw to hold the servo horn in the position that allows the flower to go from open to closed.



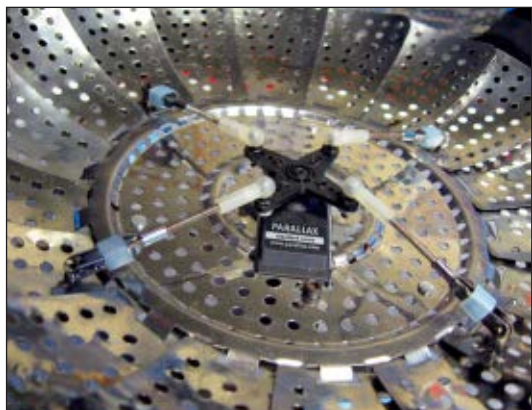
servo horn can be as close as possible to level with the petals as the petals move from their open state to their closed state. I chose to add a small stack of washers to make the servo horn more parallel with the push-points on the petals of the flower, but this may not be necessary depending on the size and shape of the steamer you are using. Your results may vary, so experimentation is encouraged.

CLEVIS, PUSH RODS, AND BALL LINKS

Open the packages and retrieve one ball link and one clevis from

■ FIGURE 16. The Power Flower should be able to fully open and close after adjusting the petals and hinges where the petals meet the base.





■ FIGURE 17. The Power Flower in a fully-open position.



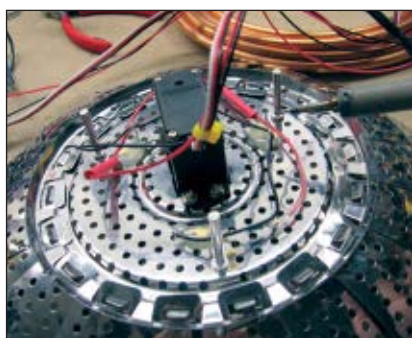
■ FIGURE 18. Kym Graner creating an interior for the Power Flower.



■ FIGURE 19. Vern and Kym Graner testing the flower centerpiece.

each package (Figure 8). Cut four lengths of 2-56 threaded rod approximately 1.75" long. The threaded rod I had was easily cut with a good pair of tin snips. The length isn't critical as both the clevis and the ball link allow you to adjust the length of the entire assembly, much like a turnbuckle. Attach one of the ball links and one clevis to each piece of threaded rod making four links as shown in Figure 9. Attach each ball link to one of the points of the servo horn as shown in Figure 10.

■ FIGURE 20. Attaching some LEDs to the flower base allows the flower to "glow" from the inside.



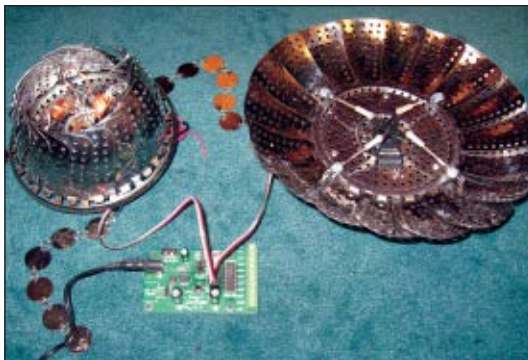
MOUNT FABRICATION

Finding a secure way to mount the clevis to each of the steamer petals was an idea from P.Y. Hung, a long-time member of The Robot Group and one of the roboteers that worked on building a Power Flower for an interactive sculpture called "The Mechanical Flower." P.Y. simply soldered a washer into the slot of a pan-head screw to make a simple and elegant mounting point for each push rod (Figure 11). Make sure you

use forceps or needle-nose pliers to hold the screw as you do this as the piece will get very hot. It might be best to have another set of hands or a small vise to make sure the washer stays in place when heat and solder are applied.

Once you have made four of these screw eyes, mount one to each petal (Figure 12). Note carefully the position shown in Figure 11 as there is normally only one hole in the petal that will allow the flower to open and close completely and not bind. Once

■ FIGURE 21. Two Power Flowers connected to an EFX-TEK Prop-1 board.



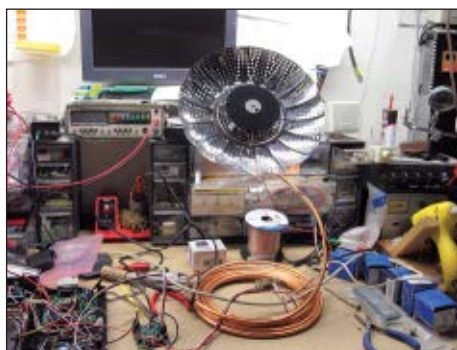
■ FIGURE 22. LEDs bent to shine outwards to light the petals. The 3.5" floppy disk hides the light source.



■ FIGURE 23. Power Flower with 3.5" floppy disk center.



■ FIGURE 24. Power Flower mounted on a "stem" of 1/4" copper tubing.



■ FIGURE 25. The component parts for Denise Scioli's "Mechanical Flower" sculpture.

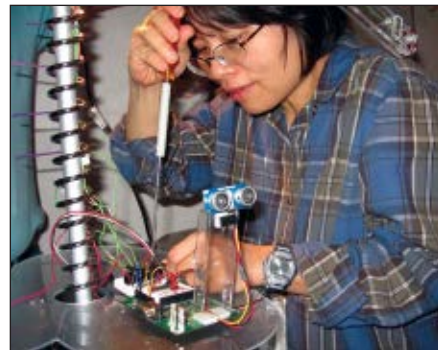




■ FIGURE 26. Denise Scioli test-fits a Power Flower in the Mechanical Flower steel bowl.



■ FIGURE 27. Clear Acrylic "leaves" being added to the Mechanical Flower.



■ FIGURE 28. P.Y. Hung wiring up the Sonar Sensor for the Mechanical Flower.



■ FIGURE 29. Denise Scioli and P.Y. Hung with the Mechanical Flower sculpture at Dorkbot in Austin.



■ FIGURE 30. Kym Graner at Dorkbot describes the creation of the "ShyUltraViolet" sculpture.



■ FIGURE 31. The ShyUltraViolet Power Flower sculpture by Kym and Vern Graner.

in place, you can opt to position the securing band onto the clevis (Figure 13), but I've found it not a necessity as these bands are really designed to hold the clevis together in the face of buffeting winds that rattle the control linkages of model aircraft. If you

prefer an all-metal look, you can omit these.

Once you have all four clevises (clevi?) mounted, you should push the servo horn down onto the servo and attempt to rotate the servo through its full sweep from open (Figure 14) through midpoint (Figure 15), and finally to the full-closed state (Figure 16). In most cases, you will have to twist the servo a bit then lift and drop the horn back on it when you hit the servo end stop point. You should position the horn on the servo so that the full-open to full-close states leave a bit of slack. It's best not to hit the end-stop of the servo during the range of motion of the flower (Figure 17).

DECORATION TIME!

Now that you have a completely assembled Power Flower, it's time to brighten it up a bit with some decorations. Kym decided to make some artificial stamens out of springs, copper tubing, and solder wick (Figure 18). We attached it to the

center of the flower using hot-melt glue (Figure 19). Once we had the center decorated, I took the flower back to my workbench to add some black light LEDs to the inside base of the flower (Figure 20).

I then built a second Power Flower. I connected both flowers to an EFX-TEK Prop-1 microcontroller (Figure 21) and then re-purposed some code to make the flowers move through their range of motion in a pseudo random pattern. The EFX-TEK controller is really handy and inexpensive. It uses the venerable Parallax BASIC Stamp 1 as its brain and the software posted with this article can control up to six flowers from this single controller.

After checking out the motion, I decided that the second flower needed a center of some type. Looking around, I spotted an old 3.5" diskette. I cracked open the housing, took the

PARTS LIST

- 1 Vegetable Steamer 6" (grocery store)
- 1 Parallax standard servo part #900-00005 (www.parallax.com)
- 1 EFX-TEK Prop-1 controller part #31101 (www.efx-tek.com)
- 1 Great Planes 2-56 threaded ball links part #GPMQ3841 (www.greatplanes.com)
- 1 Great Planes 2-56 threaded steel clevis's part #GPMQ3791 (www.greatplanes.com)
- 2-56 threaded rod (hobby store)
- Misc. washers, nuts, and bolts

mylar media (Figure 22), and glued it to the center of the flower using some screws as stand-offs (Figure 23). I mounted this second flower on a temporary stand of 1/4" copper tubing (Figure 24) for testing.

By now, I was playing with an idea for a robotic sculpture that would cause the flower to open or close based on ambient sound levels around the flower. My wife dubbed the concept the "ShyUltraViolet" and I put together a concept video that describes this concept and then shows the flower going through a sequence of full-closed, to full-open (see Resources for video link).

THE MECHANICAL FLOWER

I was showing the prototype Power Flower around at one of the Robot Group's meetings when Denise Scioli and P.Y. Hung took an interest in creating one of their own. Denise had a concept for enclosing the flower in a very industrial-looking metal shroud that would be suspended from an industrial dishwasher hose spring (Figure 25).

Denise built one of the Power Flowers and placed it inside the bowl (Figure 26) where the reflections of the petal motions were greatly amplified. She also worked on

creating some clear acrylic petals (Figure 27) to surround the flower and P.Y. worked on wiring these up. They then worked together to design software for the BASIC Stamp 2 that would change the flower's position and lighting based on using a Parallax Sonar Sensor to determine the distance of the observer from the front of the sculpture (Figure 28).

DORKBOT HERE WE COME!

Since we have a very active "Dorkbot" community (see Resources for link) in Austin, we decided that it would be an idea venue for us to display the Power Flowers in their different guises. Denise and P.Y. brought out the Mechanical Flower (Figure 29) and Kym talked about the creation of the flower (Figure 30) and showed off the prototype ShyUltraViolet (Figure 31).

I hope these examples are inspirational and that you will consider making your own Power Flower. The device should be easy to build in a single weekend and the resulting motion is down-right hypnotic to watch. You can drive the servo with any microcontroller you have handy and decorate the flower

RESOURCES

- EFX-TEK: www.efx-tek.com
- Parallax: www.parallax.com
- Dorkbot Austin: www.dorkbotaustin.org
- ShyUltraViolet / Power Flowers Video: www.youtube.com/VernGraner
- The Mechanical Flower: <http://makerfaire.com/pub/e/838>
- The Robot Group: www.TheRobotGroup.org
- The Workbench Design Challenge: <http://forum.servomagazine.com/viewtopic.php?t=8180>
- Nuts & Volts Web Forum: <http://forum.servomagazine.com/viewtopic.php?t=8180>

with any technical flotsam and jetsam that may have washed up on the shores of your shop.

If you do build a Power Flower, please drop me a note and let me know how it's working for you. As always, I can be reached at vern@txis.com. **NV**

Special thanks to Kym Graner and Denise Scioli. Also, I'd like to say a special thank you and good luck to Pui Yee Hung, a long time roboteer who is leaving Austin for the wilds of New York. We'll miss ya P.Y.!

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READER FEEDBACK continued from page 60

all four on the CD4028 inputs. For instance, a BCD value of binary 1001 (arranged DCBA) will post a logical high on the CD4028's 9 output pin (1000000000). Any binary number greater than 9 will not post a logical high on any of the CD4028 output pins as valid BCD numbers are 0 through 9. Also, the CD4028 was specially designed for this purpose, as there are only CD4028 decode outputs for the numbers 0 through 9.

Although the language of the Pop Quiz was a bit faulty, the concept offered by the example is correct. One must realize that some components have multiple identical elements that all do the same job. In that case, the designer must keep up with which elements are associated with a particular task and attach the

device pins accordingly. One could use any of the 74LS373's eight D latches independently. However, I've not seen that done very often and a 74LS74 dual D flip flop would be an alternative and possibly better choice if only one or a couple of standard D latches were needed in the design. On the other hand, the CD4028 is not a device that contains multiple identical logic elements. Thus, a special purpose within the application such as memory-mapped address decoding or octal/BCD conversion would have to exist before the CD4028 could be considered for the design. As with the multiple element integrated circuits, the designer must pay particular attention to detail when wiring in the CD4028.

Peter Best

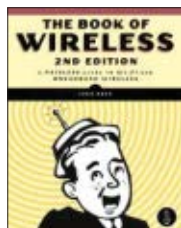
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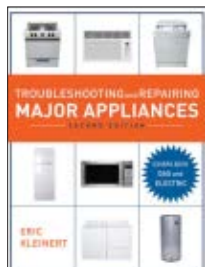
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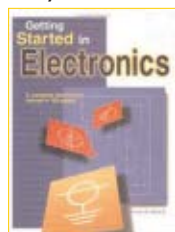
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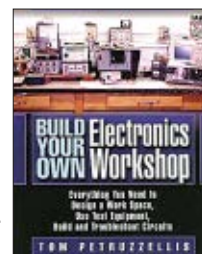
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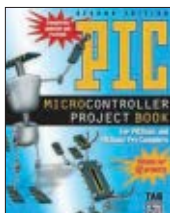


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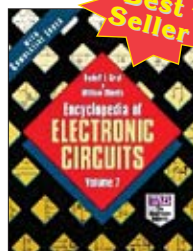
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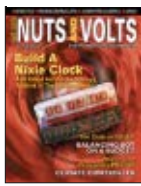
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As seen on the
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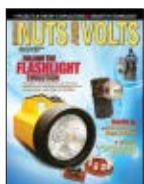
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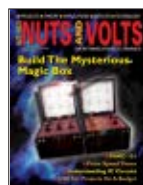
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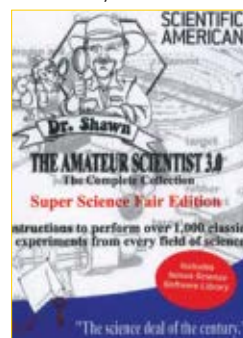
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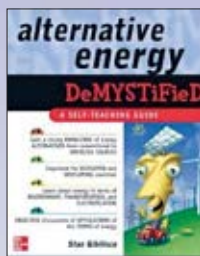
ALTERNATIVE ENERGY SECTION



Alternative Energy Demystified by Stan Gibilisco

Publish Date: October 23, 2006

The fast and easy way to get up-to-speed on alternative energy. Because of current events, geopolitics, and natural disasters, the cost of fuel is front and center in our lives. This book provides a concise look at all forms of energy, including fossil fuels, electric, solar, biodiesel, nuclear, hydroelectric, wind, and renewable fuel cells. You will get explanations, definitions, and analysis of each alternative energy source from a technological point-of-view. **\$19.95**



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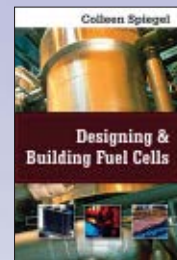


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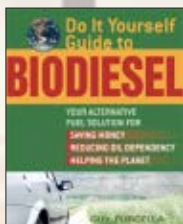
Designing & Building Fuel Cells by Colleen Spiegel

Designing & Building Fuel Cells equips you with a hands-on guide for the design, modeling, and construction of fuel cells that perform as well or better than some of the best fuel cells on the market today. Filled with over 120 illustrations and schematics of fuel cells and components, this "one-stop" guide covers fuel cell applications, fuels and the hydrogen economy, fuel cell chemistry, thermodynamics and electrochemistry, fuel cell modeling, materials, and system design, fuel types, delivery, processing, and much more. **\$89.95***



Do It Yourself Guide to Biodiesel by Guy Purcella

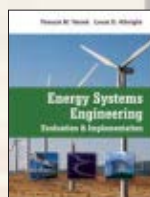
Contains the most current and complete information available for would-be biodiesel makers. This book offers a step-by-step path from the initial desire to do something good for the environment to the final stage of filling the tank with low-cost fuel. Readers are given a complete understanding of what biodiesel is and how to make it properly and safely. There is even a section on pitfalls to avoid, as well as the author's personal tips and tricks. **\$15.95**



Energy Systems Engineering by Francis Vanek, Louis D. Albright

Publish Date: June 13, 2008

A unique systems approach to energy engineering, covering carbon-based, nuclear, and renewable sources! Filled with over 200 detailed illustrations and tables, the book examines short-, medium-, and long-term energy options for the remainder of the twenty-first century. For each energy system, the authors provide equations and problems to help practitioners quantify the performance of the technology and better understand its potential. **\$89.95***



The Complete Idiot's Guide to Solar Power for Your Home by Dan Ramsey / David Hughes

Publish Date: May 2007

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All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams* should be computer generated and sent with your submission as an attachment.

QUESTIONS

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- ③ Problem Solving
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>>> QUESTIONS

My furnace/air conditioning servicer recently replaced the control unit in my high-efficiency furnace. The defective portion of the control unit turned out to be the spark generator, but, in the process I see the unit has a single-wire electric flame sensor, not the old standard thermocouple. I can't figure out how the thing works. Can someone please enlighten this old-timer?

#7081

**Anonymous
via email**

Can a security system be built that would utilize a switch on a door to trigger a cell phone to call a number? A similar system on the Internet costs around \$300. Can something be built for less than \$100 with a "pay as you go" wireless phone?

#7082

**Steve Plaskon
via email**

How can I interface data collecting hardware (data loggers and real-time hardware) with Microsoft Excel through serial or USB ports?

#7083

**Wolfgang Bernardy
via email**

If you have a question you'd like our readers to address, email it to forum@nutsvolts.com

>>> ANSWERS

[#4082 - April 2008]

I have a ROSS shortwave receiver RE8000.

When Ross went out of business, so went most of their schematics and documentation. Does anyone have a schematic or know where I can get any 8000 model range information? Also, operating data on a FSE5006 PNP transistor, same problem.

#1 Although I am unable to help with the first part of your question, I may be able to assist with the second part: the FSE5006 may simply be a Fairchild Semiconductor SE5006. My ECG replacement guide lists an ECG108 as the cross reference. An obsolete product search at Fairchild Semi turned up nothing. The ECG108 is, however, an NPN-Si, RF/IF/Video Amp, Osc, Mix, VHF/UHF, BVcbo = 30, BVceo = 15, BVebo = 2, Ic max = 50 mA, Pd = 0.6 W, ft = 800 MHz, hfe = 20 min, TO-92 case.

**Walter Heissenberger
Hancock, NH**

#2 Schematics and service manuals for these seem very hard to find. I suggest that you post a wanted ad or message on Internet BBS (bulletin boards) or Newsgroups that specialize in radio collecting and repair. Hopefully, someone has a paper version for

copying. A 1970s vintage radio is not too hard to reverse-engineer and make your own service schematic.

The FSE5008 is probably a typo. The "F" may be the Fairchild company logo. The SE5008 is a generic NPN transistor that was sourced by several vendors in the 1970s. It crosses to a complementary NPN/PNP pair (2N5818 and 2N5819). Here's the datasheet for this family: <http://tinyurl.com/2482ye>

**Peter Stonard
Campbell, CA**

[#5081 - May 2008]

I'd like to use a white LED to light up a wall-mounted keepsake box (like a picture frame, but thicker). It should light with a pushbutton and turn itself off after an hour or two and use as little current as possible when off.

#1 This simple LED timer circuit in Figure 1 uses a PICAXE 08M. Duration of the timer is set by the 'for - next' loop and pause delay. Best of all, there's no current drain when it's OFF. Brightness of the LED can be adjusted by changing the value of RL.

Code for one hour duration:

```
main: high 1          ' turns on xistor switch and LED
    for b0 = 1 to 60 ' loop 60 times ( for b0 = 1 to 120,
                        ' for 2 hour duration )
        pause 60000    ' delay = 60 seconds
    next b0
    low 1              ' turn off xistors and LED
```

**Steve Ghioto
Jacksonville, FL**

#2 There are several ways to design a timer for your project. The most simple and elegant is to use an 8 pin microcontroller (uC) such as a Tiny AVR as shown in Figure 2. The only other components would be a GP MOSFET transistor (such as 2N7000), a ballast resistor for the white LED, a decoupling capacitor across the battery, plus the white LED and a push switch, of course. Also shown in the diagram is the standard six-pin ISP connector needed to program the AVR. If the uC is pre-programmed before assembly, then the connector can be removed. The typical white LED draws 20 mA with 3.2V drop, and this current is set by R3. When Idle, the uC draws a couple of milliamps, but can also be put into a low power sleep mode drawing

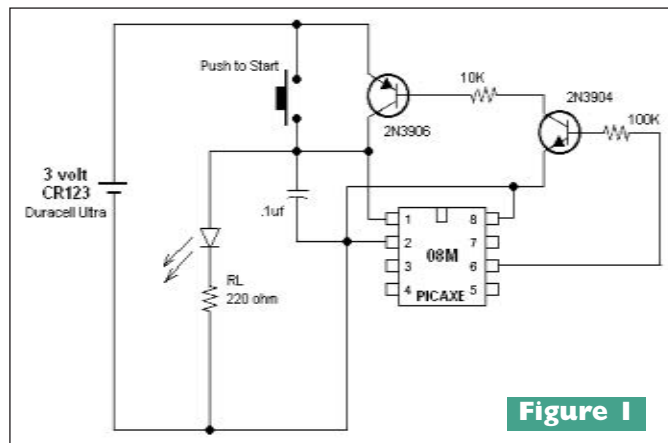


Figure 1

only micro-amps. When the button is pushed, the uC wakes up, turns on the white LED, and counts the internal uC timer pulses every second. After 100 minutes (6,000 counts), the white LED is turned off and the AVR sleeps. A second LED was added as a heartbeat (at one pulse per second), to mark the passage of the long timer period. Unfortunately, this design requires writing code and programming the chip, but the firmware is easily modified for any other desired timer duration.

A 100 minute timer is hard to do with only analog components, as the large timing capacitor (about 2,200 µF) would have significant leakage current. A simple circuit built around two CMOS digital ICs is shown in Figure 3 and uses an oscillator at 1/3 Hz followed by a 12-bit counter to count

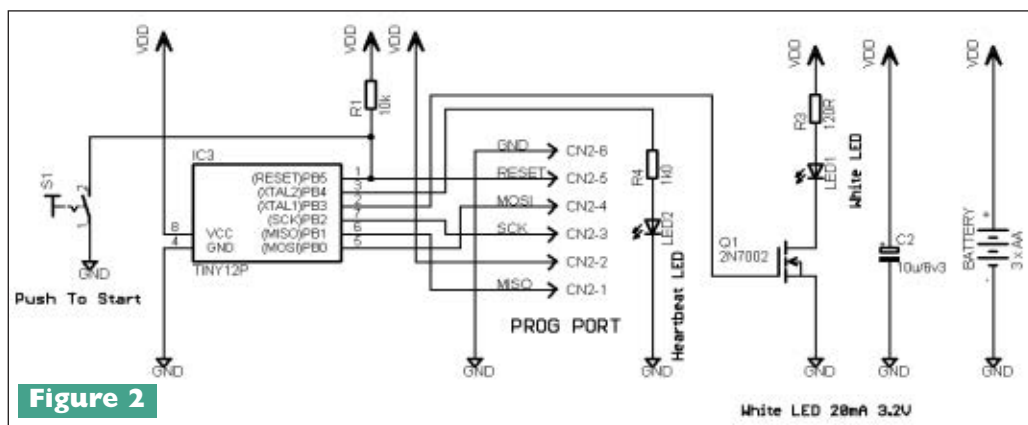


Figure 2

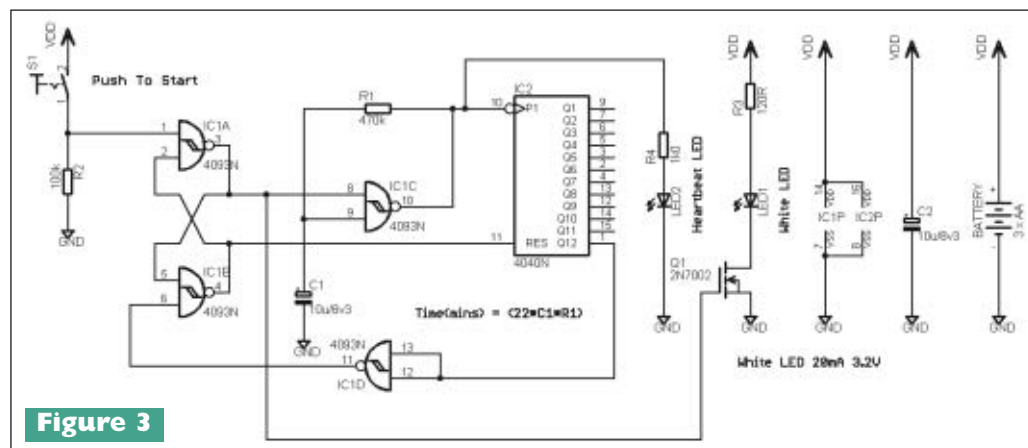


Figure 3

6,144 seconds. When idle, the circuit draws only a few micro-amps. When the button is pushed, a latch (IC1a and IC1b) is set that turns on the white LED and starts the oscillator (IC1c, R1, and C1). The pulses are counted by IC2 and after 2,048 pulses, the Q12 output is set and this resets the latch, clears the counter, and turns off the white LED. A

second LED was added as a heartbeat (on and off for three seconds each), to mark the passage of the long timer period. In each case, the circuit is powered from three AA size batteries and construction is not critical.

Peter Stonard
Campbell, CA

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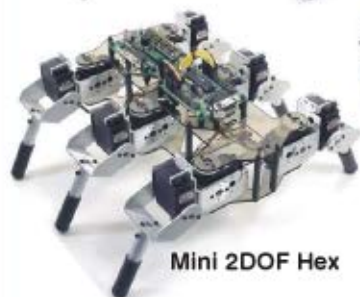
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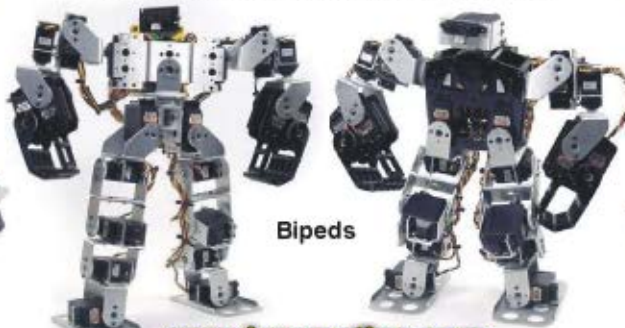
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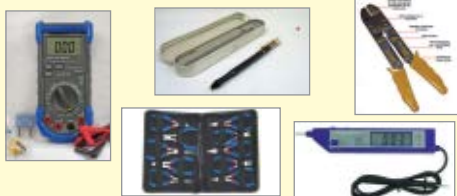
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CSI3005X5 0-30V/0-3A	\$119.00	\$114.00

Triple Output DC Bench Power Supplies

- Output: 0-30VDC x 2 @ 3 or 5 Amps & 1fixed output @ 5VDC@3A
- Source Effect: $5 \times 10^{-4} = 2mV$
- Load Effect: $5 \times 10^{-4} = 2mV$
- Ripple Coefficient: <250uV
- Stepped Current: 30mA +/- 1mA
- Input Voltage: 110VAC



Item #:	Price 1-4	Price 5+
CSI3003X3 0-30Vx2@3A	\$188.00	\$183.00
CSI3005XIII 0-30Vx2@3A	\$249.00	\$234.00

Soldering Station w/ Ceramic Element & Separate Solder Stand

- Ceramic heating element for more accurate temp control
- Temp control knob in F(392° to 896°) & C(200° to 489°)
- 3-prong grounded power cord/static safe tip
- Separate heavy duty iron stand
- Replaceable iron/easy disconnect
- Extra tips etc. shown at web site



Item #
CSI-STATION1A
\$39.95!

Also Available w/ Digital Display & MicroProcessor Controller

Item #
CSI-STATION2A

\$51.95



ESD Safe CPU Controlled SMD Hot Air Rework Station

The heater and air control system are built-in and adjusted by the simple touch of the front keypad for precise settings. Temperature range is from 100°C to 480°C / 212°F to 896°F, and the entire unit will enter a temperature drop state after 15 minutes of non-use for safety and to eliminate excessive wear.



Only \$159.00!

Item#
CSI825A++

Our Premium All in One Repairing System

- Combines the function of a Hot Air Gun, Soldering Iron and a Desoldering Gun.
- Microprocessor controlled ESD safe unit with all digital display
- Desoldering tool comes with zero crossing circuitry preventing electrical surges and equipped with air cylinder type strong suction vacuum pump.
- The 24V soldering iron is compatible with the compound tip design.
- Uses lead-free or standard solder.



Only \$249.00!

FREE CSI486 Smoke Filter (a \$27.99 value) with the purchase of a CSI-9000

Item#
CSI-9000

ESD Safe SMD & Thru-Hole Rework Station

This multi-purpose station is perfect for all your surface mount and thru-hole requirements. The ESD safe soldering iron uses a ceramic heating element for fast heat up & stable temperature control. Comes complete with 3 hot air nozzles



Only \$169.00!

Item#
CSI906

If you have not yet programmed an SX, now is the time to get started. Parallax offers free development software, including SX/B, a BASIC language compiler for the SX microcontroller designed to help the transition from higher-level programming to assembly language.

Using the new SX-Key® USB, the primary development tool for the SX line of microcontrollers, you can program SX chips in-system and perform in-circuit source-level debugging.

The SX Tech Tool Kit is well-equipped with supporting material that makes it a great starting point to begin developing projects with the SX microcontroller. Upon receiving the kit, you will be able to program SX chips within the hour.

The **SX Tech Tool Kit** includes:

- SX-Key USB
- SX Tech Board
- (2) SX 28AC/DP 50 MIPS chips
- (1) 50 MHz resonator
- (1) 4 MHz resonator
- Scrolling Text Medal
(Available in kits while supplies last)
- SX-Key USB Manual v2.0
- Programming the SX Microcontroller Book by Gunther Daubach
- USB cable

We recommend a 7.5VDC 1 Amp Power Supply (sold separately; #750-00009; \$10.95).

Program with the SX microcontroller



SX Tech Tool Kit
(#45180; \$89.95)

Order the **SX Tech Tool Kit** (#45180; \$99.95) online at **parallax.com** or call toll-free **888-512-1024** (Mon-Fri, 7 a.m. - 5 p.m., PDT).

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